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Spectra™ Products

HPQ-2S MANUAL

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As part of our continuous product improvement policy, we are always pleased to receive your comments and suggestions about how we should develop our product range. We believe that the manual is an important part of the product and would welcome your feedback, particularly relating to any omissions or inaccuracies you may discover.

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Requests for service may also be made at the numbers given above.

1. Introduction

The HPQ-2S is a special, small-scale quadrupole mass analyzer system designed specifically for improved operation at pressures beyond the range of conventional, full-size residual gas analyzers (RGA's). An RGA ionizes molecules of the gas in a vacuum chamber, injects them into a quadrupole mass filter (which allows only the ions of a specific mass to charge ratio to pass through), and collects the current that passes on a detector electrode.

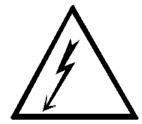
This type of instrumentation has many applications and works well where the pressure is low enough to allow ions to travel the length of the analyzer without colliding with other gas molecules. Under normal operation conditions, increasing the pressure of a gas increases the detected current of its ions linearly. However, as total gas pressure increases to the point where ions are likely to collide with gas molecules in the vacuum, gas scattering begins to degrade the signal. In a normal open source RGA, signal deterioration begins in the 10^{-5} Torr range and "rolls over" (i.e., the signal decreases with increasing pressure) in the 10^{-4} Torr range.

Traditionally, extending the use of RGA's to monitor gases at pressures above 10^{-4} Torr, with acceptable instrument performance, requires isolating the quadrupole from the high pressure sample source and independently pumping the RGA to maintain a sufficiently low pressure environment for it. The miniaturization of the HPQ 2 shortens the distance ions must travel and thereby extends the pressure range in which it can be used directly, without differential sample pumping, to about 10^{-3} Torr. Above this pressure, rollover begins and several other gas-species-dependent sensitivity losses occur. Fortunately, in a well-made instrument, these effects are predictable and reproducible and can be characterized.

The innovative construction of the HPQ 2 (patent pending) permits mass analyzer performance comparable, in most ways, to that of full sized RGA's. It achieves a combination of resolution, sensitivity, and unit-to-unit consistency unavailable from competing designs. This quality enables MKS Instruments, Spectra Products to extend the useful operating pressure range to $8x10^{-3}$ Torr, which covers the needs of a large number of vacuum chambers without the cost and complication of differential sample pumping.

The HPQ 2S is a *system* based on the HPQ 2 with special operating parameter values, a high quality independent total pressure gauge, a special vacuum chamber, mode-specific calibration, and advanced linearization and gas-reaction correction algorithms. Taken together, these components make it possible to do effective residual and process gas analysis up to $8x10^{-3}$ Torr directly.

2. Safety Notes



THIS INSTRUMENT MUST BE POWERED FROM THE 24 VDC SOURCE SUPPLIED.

ANY SERVICE TO THE INSTRUMENT THAT REQUIRES REMOVAL OF ANY COVERS MARKED WITH THE ELECTRICAL SHOCK HAZARD WARNING LABELS MAY BE PERFORMED ONLY IF THE AC LINE (120/240VAC) PLUG IS **LOCKED OUT AND TAGGED OUT**.

DO NOT OPERATE THE INSTRUMENT IF ANY OF THE PROTECTIVE COVERS ARE REMOVED.

DO NOT OPERATE THE INSTRUMENT IN WET OR DAMP ENVIRONMENTS.

DO NOT OPERATE THE INSTRUMENT WHERE THE ELECTRONICS ARE EXPOSED TO AMBIENT TEMPERATURES OVER 50DEG CENTIGRADE.

3. Hardware Installation

3.1 Key Components

The HPQ 2S system consists of:
HPQ 2S analyzer
HPQ 2S control unit loaded with Core V2.50a, or later, and Application V2.50a, or later
HPQ 2 power supply
Helix (a.k.a. Granville Phillips) Micro-Ion™ gauge, PN 780012300
HPQ 2S chamber, PN 02030
HPQ 2S cable harness, PN 02047
Power extension cable, PN 02044-00xx (xx feet, as required)
RS-232 cable, PN 565-0xx (xx feet, as required)
HPQ 2 operation manual, PN 510-040
HPQ 2S Supplement, PN 02042 (this manual)

The HPQ 2S system must be run using Process Eye V1.64, or later (PN 513-020).

3.2 Power Requirements

The HPQ 2S power module supports one HPQ 2S head. It is a CE certified, international unit, requiring 100 VA from 100-240VAC, 50/60 Hz. Additional power is required for the System Control computer, the monitor and printer. The HPQ 2S power module supplies 24 VDC to the HPQ 2S and its associated Micro-Ion gauge.

3.3 Installing

The installation of the HPQ2S is relatively simple in comparison to the traditional process sampling RGA for the simple reason that there are no turbo pumps, backing pumps or pump controllers! When planning the installation however, careful consideration must given to practical matters such as filament protection, chamber access, power supply and cable run positioning, and final location of the control computer. This guide is designed to assist creation of a specific installation by covering each of the basic considerations necessary. Drawing 02073 in Appendix A is an overall installation/cabling diagram. Note that the housing is designed to permit interchanging the positions of the HPQ 2 and MicroIon gauge, but the chamber connection must be via the screened end port.

3.3.1 Filament Interlock Issues

The filaments of the HPQ 2S system can be damaged if exposed to excessive gas pressures. The HPQ2S is ideal for applications such as sputtering processes that occur at or below 8 mTorr. Continuous operation above 15 mTorr is not recommended. However, pressure bursts of up to 50 mTorr are tolerable, provided they are short in duration (< 1 sec), particularly when the bursts are of inert gas than reactive gasses such as oxygen or water vapor.

The best protection against inadvertent exposure of the filament to unacceptably high pressures is by incorporating knowledge of the operating environment into a protection scheme. Pressure considerations arise during operations such as wafer or substrate transfer and during target change or other maintenance events. A pressure gauge with a relay is often used to enable the X-Trip circuit to protect the filaments (see Section 3.4). The operation of a gate valve, particularly on a cryogenic pumped chamber, is often a good indicator of the onset of significant pressure events. The direct integration of the operation of the RGA and filament protection circuit with the computer controlling the vacuum vessel is also possible. For more information on this topic, please contact your local MKS Spectra representative.

3.3.2 Chamber Access

Access to the vacuum chamber itself should be carefully considered. The HPQ 2S comes standard with a 2 ¾” Conflat fitting. Some chambers may have alternative fittings such as the NW-40. In this case, an adapter would be required for hook up. The housing for the HPQ 2S runs straight from its mating face for a distance of 10”. Some mounting points on a vacuum system may not accommodate this reach. In this case, an angle fitting may be required. Your MKS Spectra representative can help you during the specification of an order to ensure that the mechanical requirements for hook up are satisfied.

When planning the positioning of the instrument around a vacuum chamber, care should be taken to allow for chamber access during routine chamber maintenance intervals. If the head can be positioned away from the main chamber access points or tucked in a manner that allows the service technician to stand close to the chamber during servicing, this will help prevent unnecessary handling of the analyzer itself. By considering these issues prior to installation, more efficient turn around time of the chamber is achievable by avoiding additional opening of vacuum seals.

Unless prevented by other considerations, it is desirable to position the HPQ2 Control Electronics package horizontally, with the lettering on the side panels “right side up”. This facilitates cooling of the electronics, as well as being cosmetically optimized, and affords the best thermal stability during operation. However, it is permissible to operate the unit in any orientation, and the user should consider easy access to the vacuum chamber as more important in the mounting of the HPQ 2S.

3.3.3 Power Supply and Cable-Run Positioning

The HPQ 2S power supply is separate from the analyzer and control electronics and must be placed in a position allowing access to 110/240VAC outlets and to the 24VDC connection at the back of the control electronics. No interface to the computer is required. Also connected to the HPQ 2S head, are the communications cable to the Control Computer via an RS-232 cable and an X-Trip cable.
When planning the lay out of cables, the first issue is to determine cable lengths. Prior to ordering the system, the location of the analyzer and vacuum chamber with respect to the control computer and any other cabled interface required for the installation should have been considered. The cables can be bundled during installation to provide optimum access to the vacuum chamber and permit ease of connecting and disconnecting. Careful planning and execution will produce good results. Installation with an eye for the discrete use of supporting structures, tie wrap fasteners and cable trays can lead to a lay out which is hidden during daily operation and conveniently at hand whenever maintenance is required.

3.3.4 Control Computer Location

When positioning the Control Computer, keep in mind that you might be standing at the monitor many hours working with the system and its data. Are you in a traffic flow? Does your location prevent access to the vacuum system? Are the connecting cables safely stowed? It is recommended that a comfortable chair be considered as part of the installation - detailed review of accumulated data can take time. A comfortable workstation will allow a conscientious person to perform well. If the computer is mounted on a mobile stand, ensure that it is firmly anchored to the stand. Mounting the Control Computer on a cart can make it easier to keep the system in a convenient operating location while still permitting easy relocation for maintenance access. Be aware of the cables to the computer. The cart might be mobile, but the length of its tether will limit motion. Also, the cables can represent a tripping hazard, so ensure that they are properly stowed to avoid endangering workers.

3.4 Filament Protection

Filament protection is required for the safe operation of the HPQ 2S. It is the responsibility of the user to adapt the installation as necessary and to adopt procedures as necessary to prevent filament operation of the Analyzer ion source and the Micro-Ion Gauge when exposed to pressures exceeding 15 milliTorr. **It is very harmful to these instruments to attempt to operate them at higher pressures.**

The X-Trip circuit is an electrical interlock that can be used to prevent the filaments from being on when vacuum conditions are unsafe. This should be considered a *primary* interlock. The plug provided with the HPQ 2S (PN 601100204) must be used for proper and reliable interlock operation. When this plug is inserted into the X-Trip jack on the back of the HPQ 2S controller, and its two conductors are left open-circuit, the filaments of the HPQ 2S and Micro-Ion gauge are prevented from being on. Closure of the circuit permits normal operation of the filaments. This is addressed in the HPQ 2 manual.

An example application of the X-Trip circuit is to connect the circuit through a position-indicator switch of the vacuum chamber high-vacuum isolation gate valve, so that the circuit is open when the valve is closed. Another example is to connect the circuit through a pressure set-point relay on a chamber vacuum gauge controller, so that the circuit is open when the chamber pressure is too high.

Additional filament protection is provided by a software interlock between the operation of the HPQ 2 analyzer and Micro-Ion gauge filaments. Note that this is a *secondary* interlock, NOT a substitute for a good primary interlock. The HPQ 2S system turns the RGA filament off when the pressure measured by the Micro-Ion gauge exceeds a high limit (default value 1.8E-2 Torr) or falls below a low limit (default value of 8.E-10 Torr). These high and low limits may be overridden with items "IGHiLimit" and "IGLoLimit" in the "SerialNumber.Ini" File [SYSTEM] section and are floating point values in the working units of the system.

4. Software Installation

4.1 Control Unit Downloads

The HPQ2S control unit should have a Core version of V2.50a or higher and an App version of V2.50a or higher. These files are found in the main application directory (if default installations are performed this will be C:\Program Files\Spectra\Process Eye) under the names “Core2S.img” and “App2S.img”, respectively (note that these are special version for the HPQ 2S head). Downloading is performed using the “Config” application as described in the standard ProcessEye manual.

4.2 Head “.ini” Files

The following is required in the [SYSTEM] section of all HPQ2S SerialNumber.Ini files:

HPQ2S=1

4.3 ProcessEye

Version 1.64 or higher is required to use the HPQ 2S.

5. Operation

The general operation of an HPQ 2S is described in the ProcessEye manual. The additions described below are specific to the HPQ 2S.

5.1 Filament Operation

Filaments are turned ON and OFF according to the standard features of the ProcessEye software. The Micro-Ion gauge pressure will only be tested after a warm-up period has elapsed (default 5 seconds) that can be set in whole seconds with the “IGWarmup” item in the Head.Ini File. Except for this turn-on delay between the gauge and the HPQ 2S, the filaments of these two devices go on and off together. Turning off the HPQ 2S filament also turns off the gauge filament. A filament fault in either device will also turn off the other.

The system gives a message “Filament Fail due to IG failure to switch on Filament” when turning ON the filaments if the gauge filament fails to come on in the allowed warm-up time. This can be disabled by changing the value for the “Skip Fil Message” item in the [SYSTEM] section of the SerialNumber.Ini file to set bit 5 (32) true. It is possible to override HPQ 2S dependence on an active gauge filament by adding (or changing) the “Run without Filaments” setting in the [SYSTEM] to True (it defaults to False for HPQ 2S systems).

Note that the Micro-Ion Gauge has two filaments, switch selectable on the gauge module. Standard practice is to use filament #1. It is not unusual, especially after atmospheric exposure, to need to try to turn on the filaments several times before they will work. If, after several tries to start the filaments of the system, the filament of the gauge will not turn on, it is possible that it is burned-out. In this case, flip the switch on the gauge to filament #2 and try again. When both gauge filaments are burned-out, the gauge tube will need to be replaced (contact Helix or Spectra GPS for further information). The HPQ 2S cannot be used successfully at higher pressures without a properly working gauge.

Do not confuse filaments #1 and #2 of the HPQ 2S with those on the gauge. Filament selection on these two devices is completely independent. Selection of the HPQ 2S filament is made through ProcessEye.

5.2 Modes of Operation

As explained in the INTRODUCTION, as the pressure in a vacuum chamber exceeds the normal operating range of an RGA, signal deterioration begins. Under these conditions, filament life and peak-resolution are compromised and gas peak interference increases. The HPQ 2S has been optimized for operation in this high-pressure region. However, to avoid loss of performance when operating at high vacuum, the HPQ 2S has three operating modes: RGA; High-Pressure; and Leak Hunting. Each mode provides the best possible performance for its intended range of application.

The RGA operating mode provides traditional RGA performance with high sensitivity, standard mass-resolution and spectral fragmentation patterns. This mode is most appropriate for monitoring conditions below 1.E-4 Torr.

The HP operating mode (high pressure) provides better filament life at high pressure and reduced spectral interference (reduced electron energy). It also utilizes advanced pressure-compensating linearization and gas species ionization correction. HP mode is best when monitoring at pressures from

1.E-4 to 8.E-3 Torr. To perform the most reliable and accurate pressure compensating linearization, the HPQ 2S uses a high performance miniature ion-gauge. The ion gauge readings are used to correct partial pressures in the Bar Chart and Peak Jump data acquisition modes. The ion gauge reading is also used as the total pressure.

The Leak Hunt operating mode provides best sensitivity leak tracing with helium at pressures up to 1.E-3 Torr. In this mode, analyzer settings have been optimized to detect very low levels of gas, especially helium, which may be used to identify the locations of leaks in the vacuum chamber. Leak Check mode does not utilize the ion gauge to modify the detected signal.

The ProcessEye recipe being run determines the operating mode used. The Leak Hunt mode is automatically used when running a Leak Check type of recipe. For Bar-Chart and Peak-Jump recipe types, the choice of HP mode (or not, which is RGA) is made at the first setup screen of the recipe. Thus the HPQ 2S can be used to evaluate process-chamber base-vacuum quality by selecting a recipe which configured to the RGA mode and then monitor a deposition process running in the milliTorr range by selecting a recipe configured to the HP mode. Any of the three operating modes can be selected in the Analog Scan recipe to permit set-up.

5.3 Mode-specific Tuning

In preparing the HPQ 2S for operation on a vacuum chamber, a calibration procedure must first be completed. This must be done for each of the three modes of operation: RGA; HP; and Leak Check. Calibration consists of setting and/or verifying that mass alignment, resolution, and the ion source settings are correct for that mode. This is made simple for the user in the ProcessEye Analog Scan section. The details of calibration will be explained in software set up section of this Users Guide, but it is important to remember that each of these three calibrations must be completed to get optimum performance over the entire operating range of the instrument.

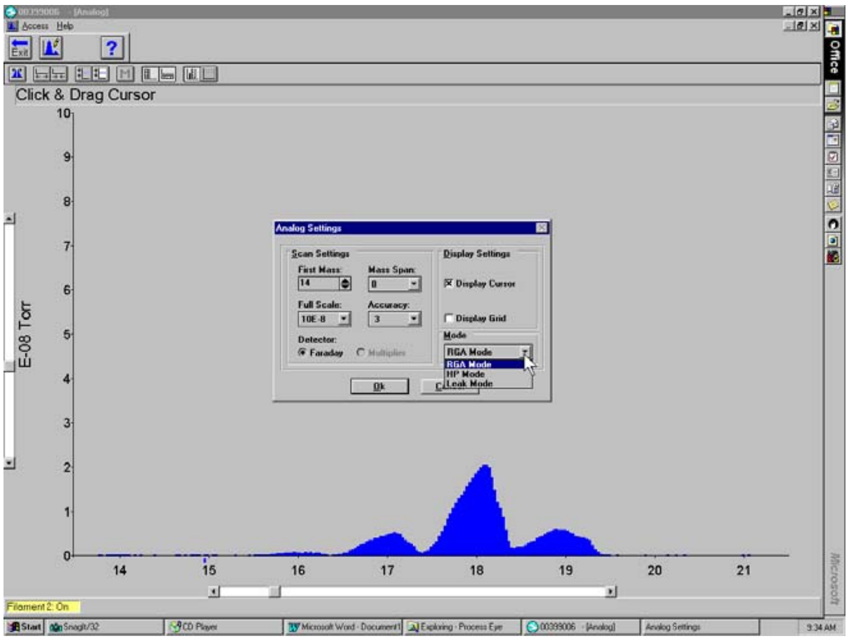


Figure 1

Calibration begins by running an Analog recipe. Right clicking in the active window of the analog scan displays the analog settings menu (Figure 1). In addition to standard ProcessEye scan settings, a Mode setting is available. The operating mode can be selected from the pull down list. To calibrate the head for operation at pressures below 2.E-4 Torr, select the RGA mode. For pressures above 2.E-4 Torr, select the HP mode. If the head is to be calibrated for Leak Check, select that mode. To permit access to the Tuning set-up box, the mass span must be set to 8. The first mass, full scale and accuracy settings should be set as appropriate to observe the particular masses of interest during calibration. Clicking OK in the set-up box updates the Analog Settings and restarts the scan with the new parameters.

Select the Tune Instrument icon in the menu bar of the Analog Scan to access the Tune settings box (Figure 2). This provides control of the mass alignment and resolution of the instrument as well as the ion source settings.

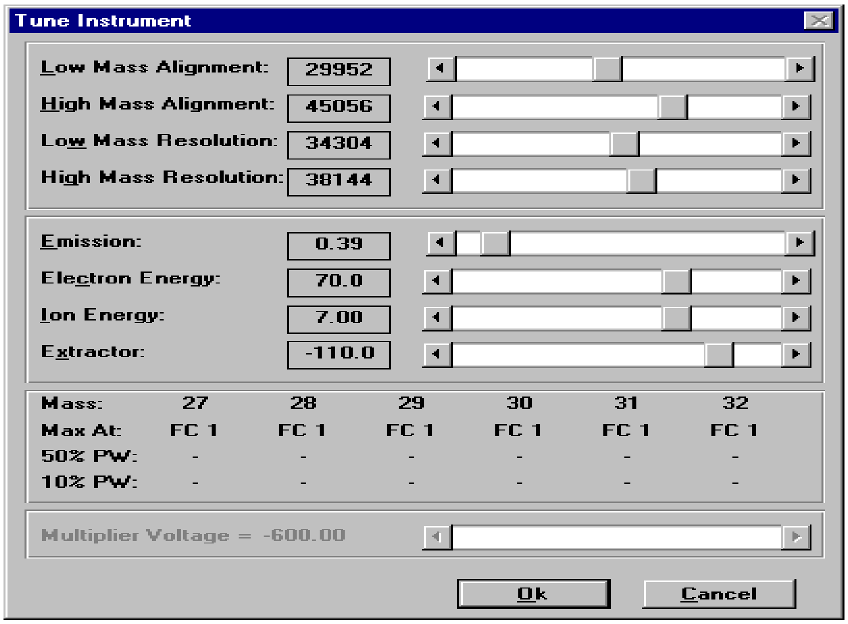


Figure 2

First, ensure that all settings for the ion source parameters match those given in the following table. Each mode has specific settings to be used. These are strongly recommended for optimum operation at the pressures appropriate for that mode.

MODE	Emission	Electron Energy	Ion Energy	Extractor Voltage
GA	0.39 ma	70.0 eV	7.0	-110 V
Leak Hunt	1.00 ma	88.0 eV	10.0	-130 V
High Pressure	0.10 ma	35.0 eV	5.0	-58.0 V

Then set the mass location and resolution, normally, for each mode. Note that the standard resolution spec is peak width <1.0 amu at 10% height in the RGA mode and <1.1 amu in the HP mode. If the pressure of the environment is controllable, it is recommended that calibration in the RGA mode be done in the low E-6 range in order to have significant peaks available. Set the chamber pressure to 3.E-3 Torr for calibration of the HP mode. The mass location and resolution adjustments should be very similar for the RGA and HP modes. The Leak Check mass location and resolution adjustments should be set the same as those of the RGA mode, except that the low mass resolution setting should be set to near zero in order to increase sensitivity for small signals at low masses.

Note: the setup and tuning must be performed separately for each of the two HPQ 2S filaments.

5.4 Mode-specific Sensitivity Calibration

In ProcessEye, HPQ 2S sensitivity is calibrated by a Faraday Cup Calibration type of recipe. The sensitivity of the HPQ 2S is different in each of its operating modes. Therefore, sensitivity calibration of the instrument must be done separately for the RGA and HP modes. Note that the sensitivity of Leak Check operating mode is set automatically from the current RGA mode sensitivity. Calibrating the two operating modes requires setting up two calibration recipes, one that is NOT set for HP Mode and one that is (Figure 3). When the calibration recipe runs, it will use the operating parameters setup for the corresponding mode.

Calibration causes the reading taken while running the recipe to match that of the reference pressure entered. Once an operating mode is calibrated, it will properly adjust the partial pressures displayed and recorded by the data acquisition recipes when using that operating mode.

When a calibration recipe is run, in addition to the regular RGA calibration, the Ion Gauge will be calibrated to the reference gas. It is important to calibrate the system at the typical operating pressure to achieve the most accurate results during normal operation. HP calibration is limited to the pressure range of 5.0E-04 to 1.0E-02 Torr (or the equivalent pressure in the units currently selected – e.g. 6.65E-02 to 1.33E00 Pascal)

NOTE that calibration must be performed separately for each of the two HPQ 2S filaments.

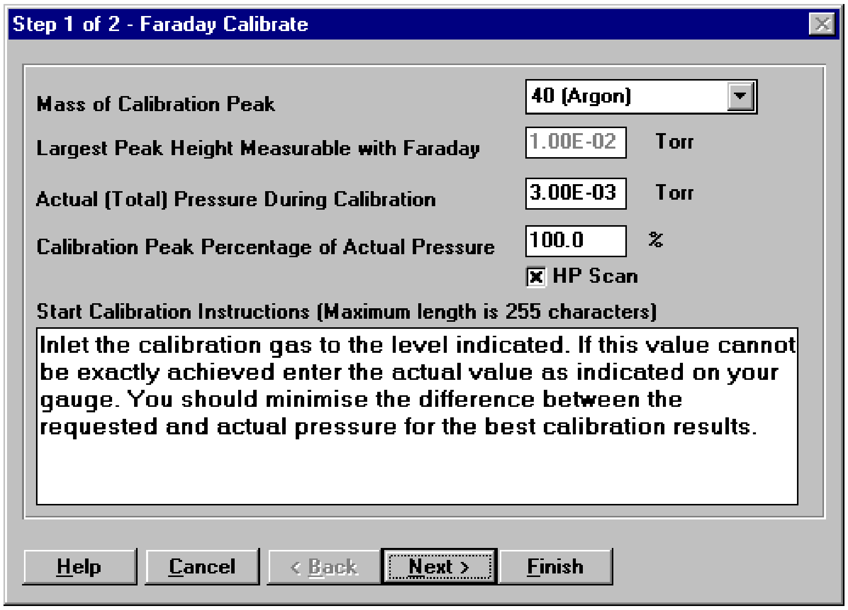


Figure 3

5.5 Mode-specific Data Acquisition

In the HP (High Pressure) Operating Mode, all partial pressure values, including the optional partial pressure trigger if it is enabled, will be corrected using a proprietary algorithm based on the measured partial pressure signal and the measured total pressure signal and the mass of the peak. To enable this correction, simply select the HP Mode on the first screen of the Bar-Chart or Peak-Jump recipe to be used for these conditions. When it is not selected (as shown in Figure 4), the head will operate in the RGA mode for best sensitivity at lower pressures. HP mode should be selected when the pressures being sampled will be above 2.E-4 Torr. We strongly recommend that the sensitivity of the HP operating mode of the HPQ 2S be calibrated at the same pressure for which it will be used to monitor.

To ensure the most accurate readings possible the total pressure is integrated during the entire scan. Since the total pressure reading is not available until the end of the scan in HP mode the partial pressure values are displayed all at once at the end of scan instead of one peak at a time.

In Bar Chart and Peak Jump modes, the Total Pressure that is optionally displayed and always stored will be the value generated by the Ion Gauge.

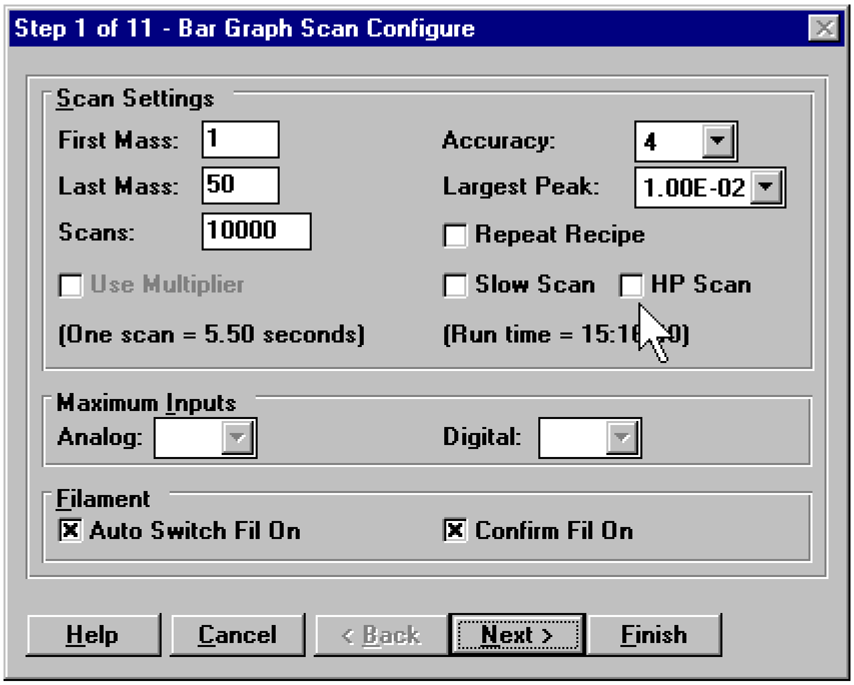


Figure 4

No total pressure based correction factors are applied in Analog or Leak Check scanning modes.
Leak Check recipes automatically use the Leak Check mode settings.

5.6 Notes on High-Pressure Effects

The HPQ 2S system effectively compensates for the consequences of high-pressure operation while still retaining most of the benefits of conventional RGA performance, but there are limits to what this can do.

Partial pressure measurement becomes increasingly non-linear in the range of 0.5 to 8 milliTorr. The HPQ 2S can correctly compensate this to within approximately $\pm$30%. For best results we strongly recommend that the system be calibrated at the same pressure it will be used to monitor. For critical applications over a range of pressure, it is possible to improve the linearity for any specific unit. If this might be true for your applications, please contact Spectra GPS personnel for further information.

Partial pressure non-linearity is also strongly gas species dependent. For example, argon sensitivity drops dramatically in the milliTorr range while that of methane drops relatively little. Therefore, the pressure-based correction required differs for different gases. The HPQ 2S is designed for best results on argon, with additional correction for several of the common residual gas species as minor components. However, there is greater unit to unit variation for gases other than argon. For critical applications for selected species at a given total pressure, it is possible to improve the accuracy for any specific unit. If this might be true for your applications, please contact MKS Spectra GPS personnel for further information.

In addition to sensitivity variation of species versus increasing total pressure, there is a dependence on the relative levels of gases due to charge transfer. The standard configuration of the HPQ 2S is optimized for accuracy of trace gases in argon. If your application differs from that, the accuracy of gas composition data will be compromised. For critical applications in other gas environments it is possible to improve the accuracy for any specific unit. If this might be true for your applications, please contact MKS Spectra GPS personnel for further information.

The HPQ 2S corrects for signal loss with increasing pressure, but it cannot make up lost signal. Therefore, as total pressure increases, and HPQ 2S corrects for signal loss, it also raises the effective noise floor. This means that, for most gases, the detection limits rise (become worse) as pressure rises. The net effect of these various non-linear behaviors can be some surprising impacts on observed results. One common one is that as pressure rises to 10 milliTorr, the mass 36 peak from argon (approx. 3400 ppm) becomes noticeably noisier than at lower pressures, while at the same pressure, H_2O does not become equally noisy until it is down to 600 ppm. If you obtain unexpected or unusual results your HPQ 2S, please contact MKS Spectra ASG personnel for possible assistance in data interpretation.

5.7 Macro Extensions

The Correction Factor used may be read within the macro associated with a recipe. The main use is to store uncorrected results in Action Channels if required. The syntax is:

```
Factor_for_Mass_M = HPQ2Sfactor(M)
```

where Factor_for_Mass_M is a Single variable and M is the integer Mass. Dividing the partial pressure for mass M by Factor_for_Mass_M yields the uncorrected peak height.

For special cases, the following variables (all As Double) may be read and written:

HPQ2S_M1
HPQ2S_B1
HPQ2S_BP1
HPQ2S_M2
HPQ2S_B2
HPQ2S_BP2
HPQ2S_X_Center
HPQ2S_Y_Center
HPQ2S_RSquared

6. Installation diagram