APEX INSTRUMENTS, INC.

XC-5000 Isokinetic Source Sampler

DRAFT

Operator's Manual

CONTENTS

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Introduction

The purpose of this manual is to provide a basic understanding of the ***Apex Instruments Model XC-500 Series Source Sampler Consoles and Isokinetic Sampling Systems***. Sections of the manual include System Description, Calibration Procedures, Sampling Procedures and Maintenance and Troubleshooting. The manual is based on the procedures established by the United States Environmental Protection Agency (USEPA) in accordance with Reference Methods 1 through 5 – Determination of Particulate Emissions from Stationary Sources.

The Apex Instruments XC-5000 Automatic Isokinetic Source Sampling System enables the operator to extract a gas sample from a stack *isokinetically*. The word "isokinetic" is comprised of two Greek root words "Iso" meaning "the same as" and "Kinetic" meaning "relating to motion of material bodies." ***Isokinetic Sampling*** *is therefore the extraction of a gas sample from a gas stream at the same velocity as the gas travels in the stack*. Isokinetic sampling is necessary because of the inertial effects of particulate matter in a gas stream. The isokinetic sampling ratio, or percent isokinetic (%I), is the ratio of the sample velocity at the inlet of the sampling nozzle to the stack gas velocity.

Isokinetic testing requires a thorough understanding of the first five test methods presented in Title 40 Part 60 Appendix A of the Code of Federal Regulations (40CFR60 App. A). Method 5 provides the general sampling train operation protocol but Methods 1 through 4 prescribe techniques underpinning the sampling activities associated with Method 5. Together, these methods outline the basic protocols for determining particulate concentrations and mass emission rates.

Table 1- USEPA Test Methods Applicable to XC-5000 Source Monitoring Console

Method	Description
Method 1	Determination of Sampling Location and Traverse Points
Method 2	Determination of Stack Gas Velocity and Volumetric Flow-rates
Method 3	Determination of Dry Molecular Weight
Method 4	Determination of Moisture Content in Stack Gases
Method 5	Determination of Particulate Matter Emissions from Stationary Sources

Unlike manually operated source sampling systems, the XC-5000 eliminates the time consuming effort required to perform the isokinetic sampling calculations and recording measurement data. The system's software provides a form – drive user interface and data management control for:

- Entering, calculating and storing data required to define stack traverse points adhering to USEPA Method 1 protocols.
- Configuring and performing USEPA Method 2 Stack Gas Velocity and Volumetric Flow Rate determinations, and performs required calculations and stores collected Method 2 data.
- Determining Stack Gas Dry Molecular Weight and Concentrations of Oxygen (O_2), Nitrogen (N_2,) Carbon Dioxide (CO_2), and Carbon Monoxide (CO).

- Determining Moisture Content in Stack Gases
- Performing all calculations necessary to determine the isokinetic sampling parameters, e.g., nozzle size, sample flowrate, test point locations, etc.

The basic XC-5000 sampling train is easily adapted to test for many other gaseous and particulate parameters of interest from stationary sources. Parameters of interest may include metals, polychlorinated biphenyls (PCBs), dioxins/furans, polycyclic aromatic hydrocarbons (PAHs), particle size distributions and an ever-increasing group of pollutants by adaptations of basic test methods. While the different methods are designated by other US EPA or agency method numbers, they are variations of Method 5 procedures such as using: different impinger solutions, organic resin traps, different filter media, sampling temperatures or a range of other alternative procedures.

The Model XC-5000 Series Sampling System can also be configured to perform the following isokinetic test methods and pollutants:

Table 2 - XC-5000 Application – Associated USEPA Test Methods

Method No.	Pollutants
5A	PM from Asphalt Roofing
5B	Non-sulfuric Acid PM
5D	PM from Positive Pressure Fabric Filters
5E	PM from Fiberglass Plants
5F	Non-sulfate PM from Fluid Catalytic Cracking Units
5G	PM from Wood Stoves - Dilution Tunnel
5H	PM from Wood Stoves – Stack
8	Sulfuric Acid Mist, Sulfur Dioxide and PM
12	Inorganic Lead (Pb)
13A & 13B	Total Fluorides
14	Determination of Fluoride Emissions from Potroom Roof Monitors for Primary Aluminum Plants
17	Particulate Matter
23	Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans
26A	Hydrogen Halides and Halogens
29	Multiple Metals

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101A	Mercury (Hg) from Sewage Sludge Incinerators
104	Beryllium (Be)
108	Inorganic Arsenic (As)
111	Polonium-210
201A	PM_{10} Particulate Matter (Constant Sampling Rate)
202	Condensable Particulate Matter
206	Ammonia (Tentative)
207	Iso cyanates (Tentative)
306	Hexavalent Chromium from Electroplating and Anodizing Operations
315	PM and Methylene Chloride Extractable Matter (MCEM) from Primary Aluminum Production
316	Formaldehyde from Mineral Wool and Wool Fiberglass Industries (Proposed)

Waste Combustion Source Methods in EPA – SW- 846

0010	Semi volatile Organic Compounds Formaldehyde
0011	Other Aldehydes and Ketones
0023A	Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans
0050	Hydrogen Chlorine and Chlorine
0060	Multiple Metals
0061	Hexavalent Chromium

System Description

The Apex Instruments isokinetic source sampling system consists of five (5) main components, shown in Figure 1-1:

1. Source Sampler Console which includes a dual column manometer, sample flow control valves with orifice flow meter, dry gas meter, and electrical controls. The Console is housed in a weather resistant ultra high molecular weight polyethylene (UHMW) custom designed case complete with carry strap.

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2. External Sample Pump Vane or Dual Diaphragm including hoses with quick-connect fittings and lubricator.
3. Probe Assembly includes a SS probe sheath, probe liner, tube heater, Type-S Pitot tubes, stack and heater Type K thermocouples and an Orsat line.
4. Modular Sample Case includes hot box for filter assembly, cold box for impinger glassware, and electrical connections.
5. Umbilical Cable includes electrical and pneumatic lines to connect the Modular Sample Case to the sample pump and Source Sampler Console.

SOURCE SAMPLER CONSOLE

The Source Sampler Console is the operator's control station that monitors gas velocity and temperatures at the sampling location and controls system sampling rate and system temperatures. Figure 1-2 illustrates the Apex Instruments Model XC-5000 Source Sampler Console's front panel.

Figure 1 - XC5000 Source Sampling Console

Field assembly and set-up is simplified. The connections for sample line, Pitot tube lines, vacuum pump (non-reversible), and electrical (4-pin circular connector and Thermocouple jacks) are all located on the front panel for easy access.

The XC Case has a removable front and back covers for easy access.

Table 3 - System Features and Specifications presents the "features and specifications" of the XC-5000 system.

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Table 3 - System Features and Specifications

Feature / Component	Description
User Interface Software	Windows XP & Higher;
Communications	Integrated data acquisition board with WAN/LAN/USB connectivity; wireless and wired
Gas Meter	Model AP25, Precision DGM, 0.7 liters per revolution, digital gas volume with Internal Quadrature Encoder with 6 digit LCD display, 1cc resolution.
Thermocouple Display	Seven (7) temperatures displayed simultaneously on the PC User Interface, °F or °C, Probe, Stack, Oven, Filter, Exit, AUX and DGM.
Temperature Control	Integrated temperature control via the Control and Data Acquisition Board, probe and oven with solid state relays.
Δ P +/- 2.5" (+/- 63 mm)	0.01" resolution (+/- 63mm 0.01 mm resolution)
Δ H +/- 5" (+/- 127 mm)	0.01" resolution (+/- 63mm 0.01 mm resolution)
Barometeric Pressure Sensor	17.7 in Hg – 32.5 in Hg 0.01 in Hg resolution. 450 mm Hg – 825 mm Hg 0.01 mm Hg resolution.
Umbilical Connectors	Electrical: 4 conductor circular connector grounded shell. Sample line: Stainless Steel 1/2" Quick Connector. Pitot Line: Stainless Steel 1/4" Quick Connectors (optional 3/8"). External pump: Stainless Steel 3/8" Quick Connect. Thermocouples: Type-K standard size.
Dimensions	Console: 23" x 21" x 12" (58 mm x 523 mm x 30.5 mm).

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Weight	Console: 39 lb (17.7 kg). Pump (XE-DAA mounted in UHMW polyethylene case): 30 lb (14 kg).
Power	Console: 120V / 60 Hz 220V / 50 Hz (optional), 15 A max (includes pump, probe and umbilical heaters). Pump: 120V / 60 Hz 220V / 50 Hz (optional).

The major components of the Series 5000 Source Sampler Consoles include:

- XC-5000 User Interface Software; running on Windows™ XP and higher compatible operating systems.
- Digital Pressure Transducers for ΔH, and ΔP (Bi-Directional), Barometric.
- Precision DGM, 0.7 liters per revolution, digital gas volume with Internal Quadrature Encoder with 6 digit LCD display, 1cc resolution.
- Automatic, integrated Temperature Controllers Integrated temperature control via the Control and Data Acquisition Board, with individual solid state relays for filter hot box (oven) and probe heat.
- Vacuum Gauge to display system vacuum 0-100 kPa (0-30 in. Hg).
- Integrated Elapsed Timer monitors sampling time.

XC-5000 USER INTERFACE SOFTWARE

OVERVIEW

The configuration and operation of the XC-5000 is completely controlled through the system's User Interface software and the operating system running on the XC-5000 embedded computer resident on the Console's mother board.

The software is constructed to provide a convenient, reliable and consistent methodology for all operations and basically leads the user through the process of performing a test. User interactions with the system are managed using menu buttons, user inputs fields, tabs, check boxes, etc., in specific form driven windows organized by task. All system operations including sensor calibrations and audits, test operations, viewing current system information and viewing any status alerts are initiated through the Main Screen, shown below in Figure 2, by clicking on the appropriate tab or button.

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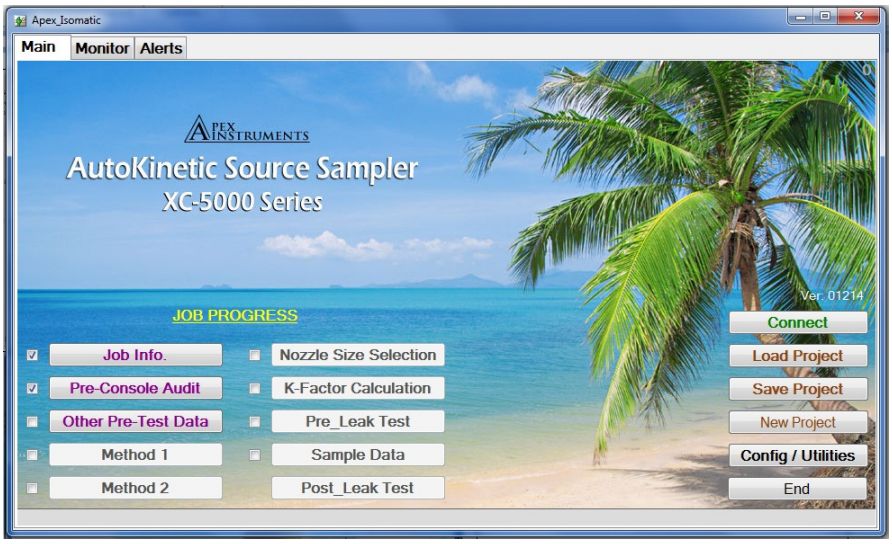

Figure 2 - Main Screen - Console is NOT Connected

Note that the Main Menu interface windows generally have three major structural components:

1. Menu bar tabs providing access to the “Main” menu window, the “Monitor” display and system status “Alerts” page.
2. Job Progress menu buttons. By completing information and procedures contained in each Job Progress menu item, in a stepwise fashion, the entire testing process is efficiently and consistently performed. As each menu item is completed, a check box is automatically displayed immediately to the left of the menu item. The next menu item becomes available when its predecessor is completed.
3. System control functions: Connect, Load Project, Save Project, New Project, Config/Utitilities, and End.

IMPORTANT: Access to many functions and operations is only possible when the software has established connection with the Console.

An active connection between the Console and the User Interface software is indicated when the current date and time are displayed on the Main window just below the Menu bar and by the text displayed on the Connect/Disconnect button. To establish the connection, simply connect an Ethernet cable to between your computer and the Ethernet connector on the front panel of the XC-5000 Console, then click the Connect. Button. Figure 2 is a screen shot of the software when it is not connected.; Figure 3 shows the display when the system is connected.

IMPORTANT: A data entry field with a yellow background indicates that field must be completed in order to continue.

Full details on using the software to configure the system to perform a test and then instruct the Console to perform the test is provided in the following chapters.

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Figure 3 - Main Screen - Console IS Connected

SOFTWARE INSTALLATION

Software installation simply requires unpacking the XC-5000 zipfile to the computer that will be used when operating the XC-5000 as follows:

1. Using Windows Explorer, locate the file named XC5000_Vxxx.zip on the CD provided with the instrument and copy it to your desktop.
2. Navigate to your desktop, locate the icon for the XC5000_Vxxx.zip file and double click the icon.
3. This will create a folder on your hard drive named C:\Apex_5 and also create a shortcut icon, shown below, on your desktop.

By default, all data and audit files created by the XC-5000 software during a test will be stored in the C:\Apex_5 folder.

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ELECTRICAL SUBSYSTEM

The Source Sampler Console is factory-configured for 120VAC/60Hz electrical power. Configuration for 240VAC/50Hz operation is an available option. The Electrical Schematics for the Source Sampler Console are presented in Appendix B.

Circuits are protected by front panel mounted circuit breakers labeled Main Reset (15 Amp for 110VAC or 10 Amp for 220VAC). Circuit breakers detect and interrupt overload and short circuit conditions, providing an important safety factor. If the circuit breaker opens, or "trips," indicating interruption of the circuit, investigate and repair the electrical fault. Then reset the breaker by pressing the circuit breaker switch.

The circuit breaker can also "nuisance trip" making it difficult to complete a test. To reduce the probability of nuisance tripping, the circuit start-up sequence can reduce the power surge. The optimum start-up sequence is to power up the sample pump first, as it has the highest current and startup surge demand. The filter and probe heaters should be powered a few seconds after the sample pump has started.

The electrical subsystem provides switched power to several circuits, including: MAIN POWER, PUMP POWER, MANOMETER ZERO, TIMER, PROBE heater and OVEN heater. All power, except the MAIN POWER, is controlled through the XC-5000 software User Interface. The User Interface also displays current readings for each temperature and pressure sensor.

- The MAIN POWER switch controls all power to all circuits. Also, when this switch is on, the cabinet cooling fan should operate.
- The PUMP POWER is activated via the PUMP POWER switch on the Console's front panel and then controlled from the "Monitor" window in the XC-5000 software's User Interface. First, plug the pump power cord into the Source Sampler Console receptacle. Next, turn on the PUMP POWER switch on the Console's front panel. Last, click the Monitor tab in the XC-5000 User Interface and then the "On" radio button on the Pump image. Figure 4 - "Monitor" Window, below, shows the "Monitor" window.

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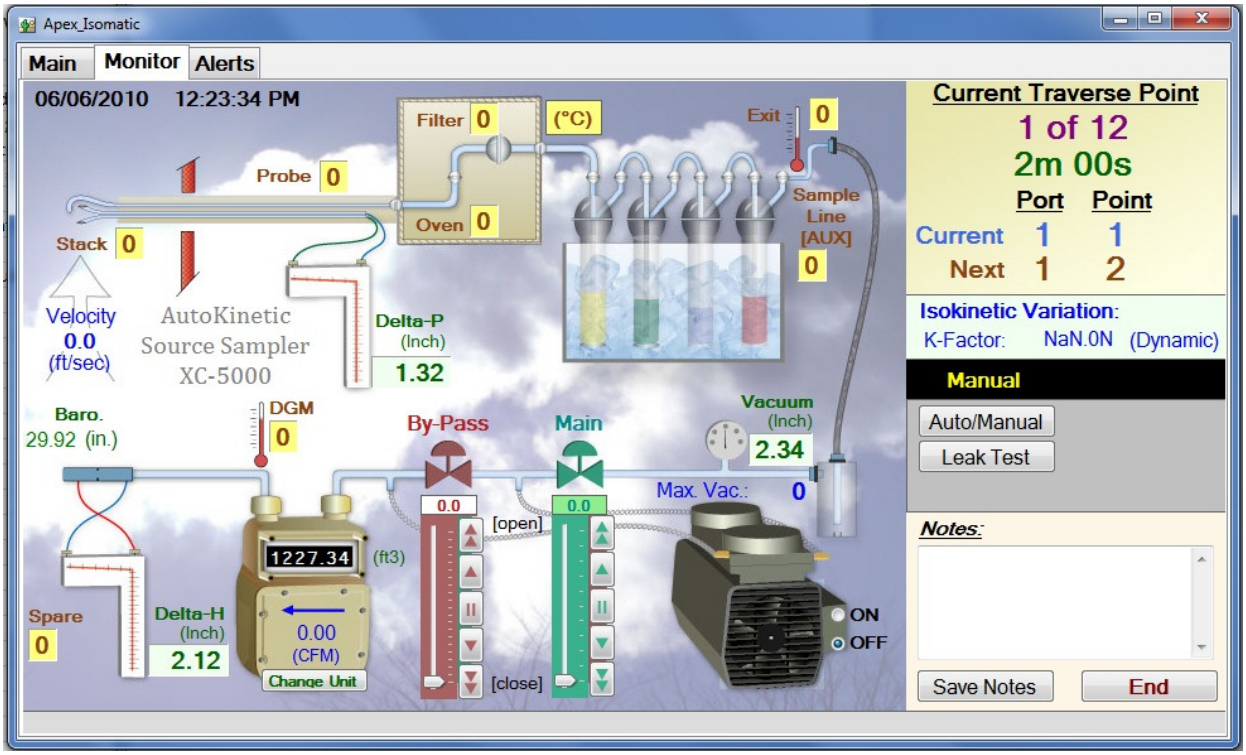

Figure 4 - "Monitor" Window

- To activate the heaters in the filter compartment (Hot Box) and the probe heater turn on the switches labeled FILTER and PROBE from the “Monitor” window in the XC-5000 software’s User Interface. The indicator lights on the SD31 Temperature automatic controllers will illuminate. The temperature controllers can be adjusted via the User Interface. Check the temperature display to verify if the heaters are working. Allow time for the temperatures to stabilize and verify operation of the circuits. The Config / Utilities interface window showing the Heater Controls is represented in Figure 5 - Config / Untilities Window , below.

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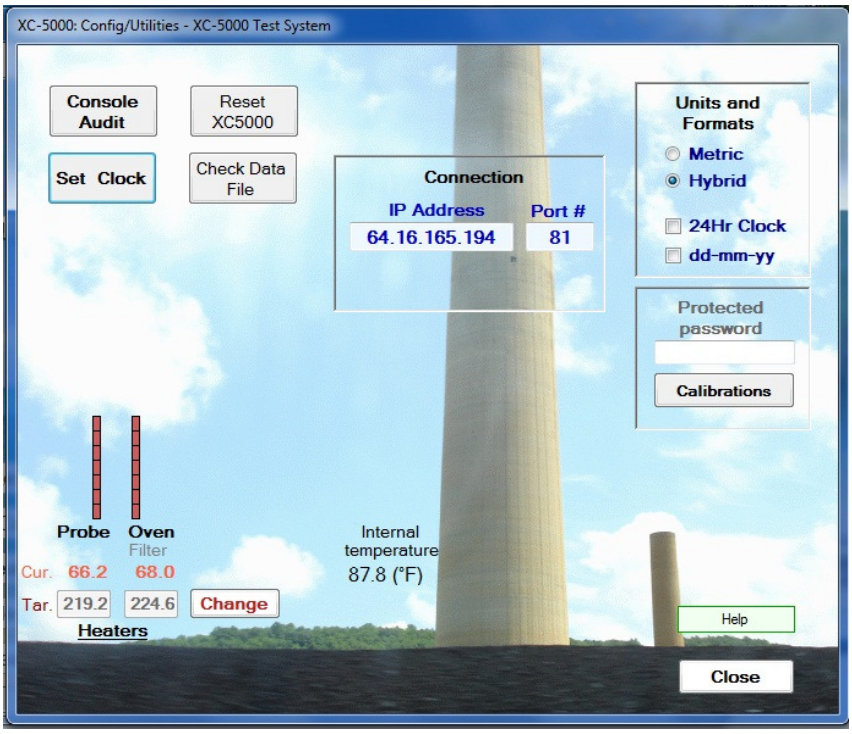

Figure 5 - Config / Untilities Window

THERMOCOUPLE SUBSYSTEM

The thermocouple subsystem displays, measures and/or provides feedback for the temperature controls critical to isokinetic sampling operation. The thermocouple system consists of Type-K thermocouples, extension wires, male/female connectors, receptacles, a 7-channel selector switch and a digital temperature display with internal compensating junction.

There are automatic temperature controllers for probe and filter oven heat which receive temperature feedback signals from the electrical subsystem to control and maintain temperatures within range of the set point. The temperature controllers are solid-state digital programmable devices. The thermocouple electrical diagram is presented in the Electrical Schematic.

All thermocouple readings are displayed on the “Monitor” screen, shown below in Figure 6, below.

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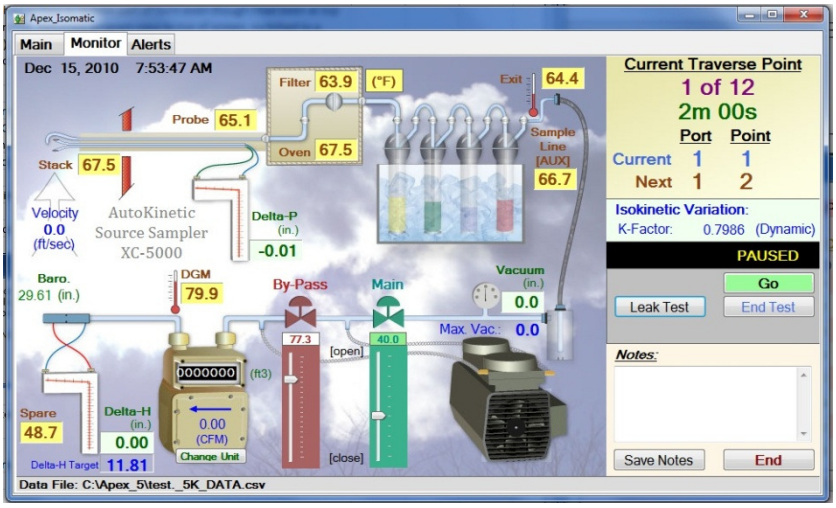

Figure 6 - "Monitor" Screen

VACUUM SUBSYSTEM

The vacuum subsystem consists of an external vacuum pump assembly, quick-connects, internal fittings, two (2) control valves (Coarse and Fine), an orifice meter and a digital pressure sensors.

The external vacuum pump assembly provides the vacuum for extracting the gas sample from the stack and then through the various components of the isokinetic source sampling system.

The sample flow rate is controlled by the Coarse Control Valve and the Fine Increase Valve through software controls in the XC-5000 User Interface “Monitor” window, shown in Figure 6, above.

This Coarse Control valve blocks the flow from the SAMPLE inlet quick-connect to the Vacuum Pump inlet.

The Fine Increase Valve allows flow to re-circulate from the pump outlet back to the pump inlet. This dual valve configuration enables very precise control of the sample flow rate.

A calibrated Orifice Tube located on the outlet of the Dry Gas Meter, indicates the sample flow rate. The orifice pressure drop is displayed in the XC-5000 User Interface “Monitor” window. The stack gas velocity pressure drop is also measured using its own dedicated digital pressure sensor. The instrument sample flow control can be managed either automatically by the system software or manually by the operator depending on the test configuration selected during software configuration. When running in manual mode, the operator can observe the orifice reading (ΔH) on the User Interface “Monitor” window, shown above in Figure 6, and quickly adjust the sample flow rate using the Fine Increase Valve control on the “Monitor” window so that the sample is extracted under isokinetic conditions.

When running in automatic mode, the system will automatically calculate the dynamic K factor and adjust the pump valves as required to maintain isokinetic sampling conditions.

EXTERNAL VACUUM PUMP UNIT

The External Pump Unit provides the vacuum that draws the sample from the stack. The pump assembly attaches to the Source Sampler Console by non-reversible 9.525-mm (3/8-inch) quick connects and an electrical receptacle. Two interchangeable pump styles are available: the E0523 lubricated rotary-vane pump; and the E-DAA dual diaphragm non-lubricated pump, with

specifications shown in Table 3. The E-0523 is a rotary vane pump that requires lubrication. The pump is shipped from the factory without oil. Thus, the lubricator jar will need to be unscrewed and filled approximately ¾ full with lightweight lubricating oil (Gast AD220, SAE-10 or SAE-5). Both pump assemblies are available in either 120VAC or 240VAC operation. Please refer to Chapter ?? for maintenance information and procedures.

The External Pump Unit contains:

- The Vacuum Pump,
- Adjustable Lubricator (E-0523 only),
- Two (2) 1.524-m (5-ft) hose extensions with 9.525-mm (3/8-inch) quick-connects configured with male connector on the pressure side and female connector on the suction side
- Enclosure Options:
    - A rigid aluminum frame that protects the pump and allows easy access, or
    - A hinged enclosure is available for either pump style, or
    - Black Polyethylene case with molded handles and removable covers.

Figure 7 - E-05323 Lubricated vane and e-daa vacuum pumps

Table 4 - Vacuum Pump features and specifications

Model Number	Features / Specifications

E-0523 (Standard Pump)	Lubricated Vane Pump Motor: 250 watts (1/3 hp), 120 VAC / 60 Hz, 1/2 Amp Measured Flow: 88 lpm @ 0.25 kPa (3.1 cfm @ 1 inch Hg); 42.5 lpm @ 3.73 kPa (1.5 cfm @ 15 inches Hg) Maximum Vacuum: 86.4 kPa (25.5 inches Hg) Weight: 15.9 kg (35 lb)
E-0523-V	Optional 240 VAC / 50 Hz
E-DAA (Optional Pump)	Double Headed Diaphragm Pump Motor: 370 watts (1/2 hp), 120 VAC / 60 Hz, 1/2 Amp Measured Flow: 82 lpm @ 0.25 kPa (2.9 cfm @ 1 inch Hg); 40 lpm @ 3.73 kPa (1.4 cfm @ 15 inches Hg) Maximum Vacuum: 89.7 kPa (26.5 inches Hg) Weight: 13.6 kg (30 lb)
E-DAAV	Optional 240 VAC / 50 Hz

PROBE ASSEMBLY

The Probe Assembly consists of the following:

- Probe Liner – 15.9mm (5/8in) OD tubing made from either Borosilicate Glass, Quartz, Stainless Steel, Inconel or Teflon®),
- Probe Heater - Removable rigid tube heater with coiled heating element, electric thermal insulation and thermocouple (Max Recommended Temperature: 260°C (500°F),
- Probe Sheath – 25.4mm (1in) OD tube with quad-assembly attached that includes a
- replaceable, modular S-type Pitot tube, stack thermocouple and a 6.35-mm (1/4-inch) OD stainless steel tube to collect a gas sample for Orsat analysis,
- Small Parts Kit – Fittings to attach Nozzle to Probe Assembly. Fittings include: 15.9mm (5/8in) union, nut and ferrules along with o-rings and backer ring.

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Figure 8 illustrates a standard Probe Assembly and a Probe Assembly with the optional 50.8mm (2in.) Oversheath and Packing Gland. The figure also details the connection between the nozzle and probe using fittings from the Small Parts Kit. Probe lengths vary from 0.914-m (3-ft) to 4.877-m (16-ft) nominal length.

Note: Effective probe length in stack = 0.305m (1-ft) less than nominal length.

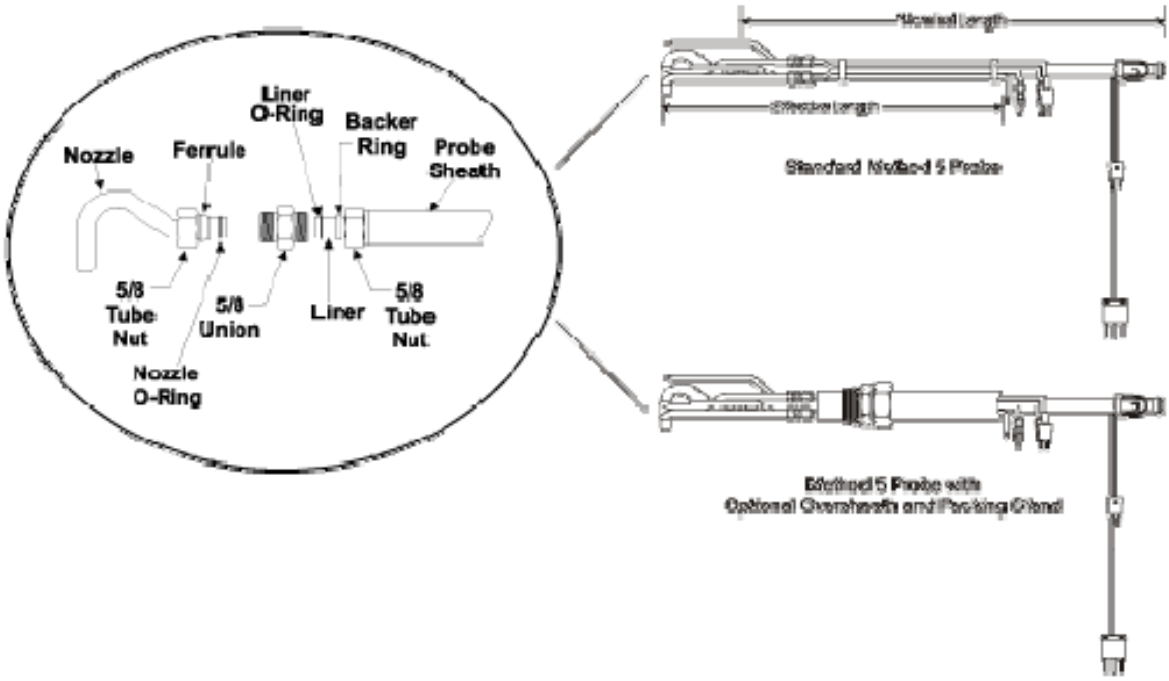

Figure 8 – Diagrams of Probes and Probe Assembly

PROBE LINER

Standard Probe Liners are constructed from 15.9mm (5/8in) OD tubing and have #28 ball joints with

o-ring groove attached. Liner materials available are borosilicate glass, quartz, stainless steel, inconel and Teflon®. Teflon® liners, straight liners and liners with integrated nozzles require a ball joint adapter. Various configurations are available, as shown below in Figure 9. Table 5 and Table 6 list the temperature limits for Probe Liner Materials and Probe Configurations, respectively.

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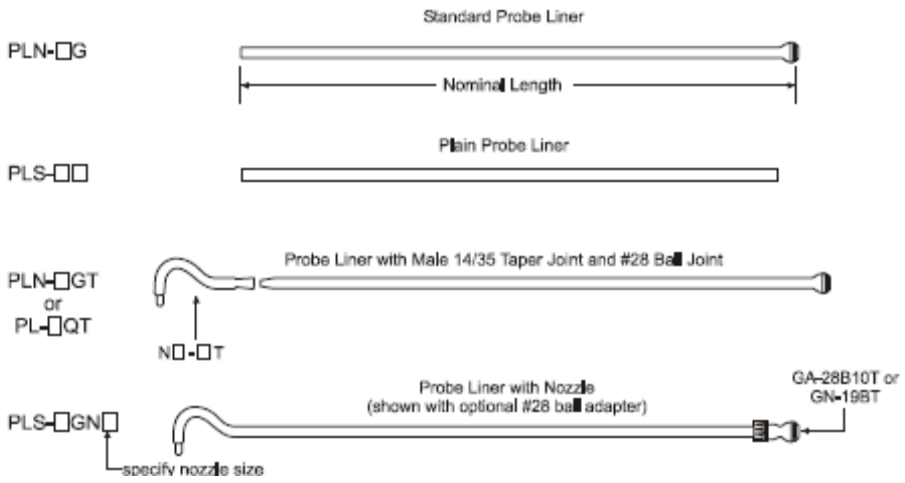

Figure 9 - Diagrams of probe liner configuration

Table 5 - Maximum stack gas temperatures for probe liner materials

Material	Maximum Temperature
Teflon" Liners and Fittings	177°C (350°F)
Mineral-Filled Teflon" Fittings	315°C (600°F)
Borosilicate Glass Liners	480°C (900°F)
Stainless Steel Liners	650°C (1200°F)
Quartz Liners	900°C (1650°F)
Inconel or Hastelloy Liners	980°C (1800°F)

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Table 6 - Probe configuration temperature range

Probe Assembly Configuration	Maximum Temperature
Stainless Steel Sheath and Glass Liner	480°C (900°F)
Stainless Steel Sheath and Liner	650°C (1200°F)
Inconel or Hastelloy Sheath and Liner	980°C (1800°F)
Inconel or Hastelloy Sheath and Quartz Liner	980°C (1800°F)

PROBE HEATER

Apex Instruments Probe Heaters are designed to maintain the temperature of the sample traveling through the probe at 120°C ± 14°C (248°F ± 25°F). Our design features a rigid tube heater with coiled heating element, electrical thermal insulation with integrated thermocouple and power cord sealed in silicone-impregnated glass insulation. This mandrel-type heater design allows for liner replacement without removing the heating element. Standard heaters are configured for 120VAC operation; 240VAC configuration is available. The maximum recommended stack exposure temperature is 260°C (500°F).

NOTE: Exposure to elevated temperatures can damage the insulation and shorten the life of the heater.

Table 7 lists the probe heater wattage required for probe nominal length.

Table 7 – Probe heater wattage requirements

Length, m (ft.)	Watts	Length, m (ft.)	Watts
0.914 (3)	325	2.74 (9) 475	475
1.22 (4)	350	3.05 (10)	500
1.52 (5)	400	3.35 (11)	525

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1.83 (6)	400	3.66 (12)	550
2.13 (7)	400	4.27 (14)	600
2.44 (8)	450	4.88 (16)	600

PROBE SHEATH

Apex Instruments stainless steel Probe Sheaths feature a one inch diameter sheath constructed from corrosion-resistant stainless steel alloy, with a modular 3/8 inch Pitot tip, 1/4 inch stainless steel quick connects at the Pitot line exit, stack temperature thermocouple and an orsat line. Inconel or Hastelloy Sheaths are available for gas temperatures up to 1800°F.

Small Parts Kit Apex Instruments Small Parts Kit (PK-SP) includes15.9mm (5/8in) union, nut and ferrules along with o-rings and backer ring as shown in Figure 8 – Figure 8.

The Probe Assembly connects to the Modular Sample Case with the following connections:

- The probe sheath is mounted to the Modular Sample Case using a probe clamp that is attached to the probe holder of the sample case.
- Extending from the probe assembly is a thermocouple male connector, which connects to female thermocouple connector of the Umbilical Cable.
- An electrical plug connects to the electrical receptacle on the Modular Sample Case Hot Box.
- The outlet ball of the Probe Liner is inserted through the entry hole of the Filter Oven (Hot Box) compartment until the back of the sheath is even with the inside of the sample case.
- The Pitot tube quick-connect lines, probe heater thermocouple, stack thermocouple and Orsat gas sample line are connected to the Source Sampler Console by the Umbilical Cable.

MODULAR SAMPLE CASE

The Modular Sample Case is used for support, protection and environmental control of the glassware in the sampling train. Figure 10 illustrates the major components and accessory connections on the Modular Sample Case. The Modular Sample Case consists of an insulated heated filter compartment (Hot Box) and insulated impinger case (Cold Box). The Hot Box features:

- Insulated (1/2 inch ceramic) filter box with dimensions 24 x 24 x 60 cm (9 1/2 x 9 1/2 x 23 1/2 inches),
- 500-watt heating element,
- Oven thermocouple with external thermocouple receptacle,
- Dual access doors,
- Handle and SS bail clip monorail attachment,
- Removable stainless steel hinged probe clamp --19 cm length (71/2 inches), and
- Stainless steel slides for connection/removal of impinger case.

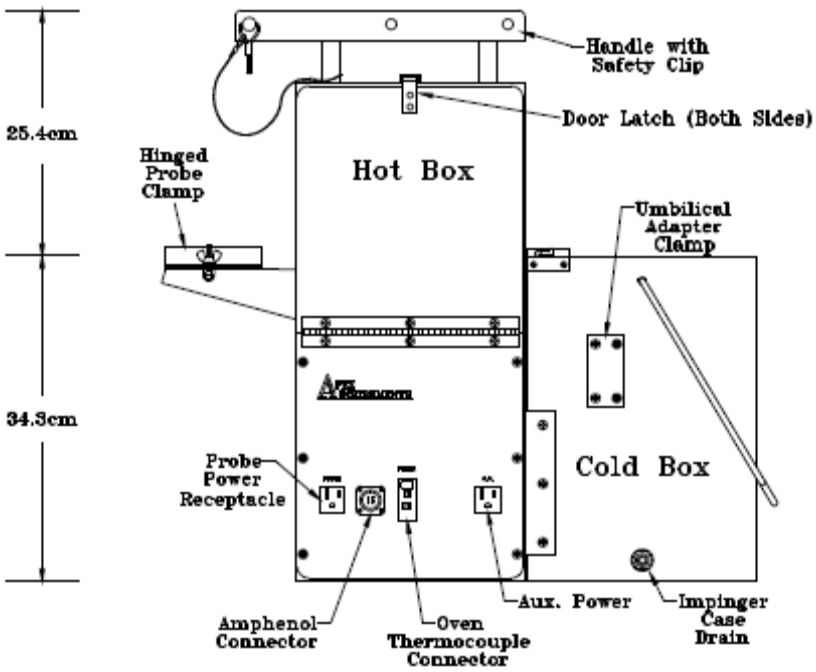

Figure 10 - Modular Sample Case Components and Accessories

The Cold Box holds the sampling train impingers in an ice bath so that the stack gas sample is cooled as it passes through the impingers to condense the water vapor. This enables measurement of stack gas moisture volume so that stack gas density can be calculated. Most testers have multiple Cold Boxes and sets of impingers for rapid turnaround between test runs. Cold Box features include:

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- Durable polyethylene foam insulation plus pre-punched foam inserts for holding the impingers in place,
- Slide on/off guides plus spring-loaded latch to prevent accidental slippage,
- Fold down handle with rope centering guide,
- High-strength plastic bracket for supporting the Umbilical Adapter
- Drain fitting for water removal as ice melts.
- Four different removable insulated Cold Boxes (Impinger Cases) are available: SB-3 holds 4 impingers, SB-4 holds 8 impingers, SB-5 holds up to 14 impingers and the SB-3C accepts inexpensive removable liners. Figure 11 depicts the standard impinger box configurations available from Apex Instruments.

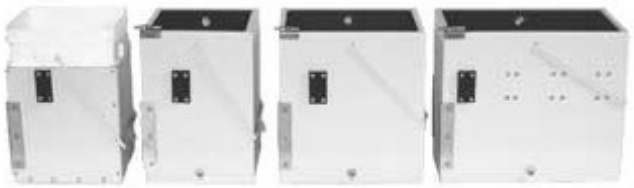

Figure 11 - SB-3C Impinger Box Caddy, SB-3 Impinger Box, SB-4 Impinger Box, SB-5 Impinger Box

UMBILICAL CABLE WITH UMBILICAL ADAPTER

The Umbilical Cable connects the Modular Sample case and Probe Assembly section of the isokinetic source sampling system to the Source Sampler Console. The Umbilical Cable contains:

- The primary gas sample line (3/8 inch i.d., blue), 12.7-mm (1/2 inch o.d.) with male quick connect to the Source Sampler Console and, at the opposite end, a 12.7-mm (1/2 inch) female quick-connect to the Umbilical Adapter.
- Two (2) Pitot lines, 6.35-mm (1/4 inch) with female quick-connects to the Probe Assembly and 6.35-mm (1/4 inch) male quick-connects to the Source Sampler Console. The Pitot lines are color-coded black and white for convenience.
- Yellow line, 6.35-mm (1/4 inch), which is intended for collecting a gas sample for Orsat analysis, can be used as a spare Pitot line.
- Five (5) thermocouple extension cables for Type-K thermocouples, which terminate with full size connectors for durability. The connectors have different diameter round pins to maintain proper polarity, and will not fully connect if reversed. Each thermocouple extension wire in the Umbilical Cable is labeled and color-coded for temperature measurement of Stack, Probe, Oven (Hot Box), Exit (Cold Box), and Auxiliary (spare).
- AC power lines for the heaters in the filter compartment (Hot Box) and Probe Assembly. The power cable terminates with a circular connector (military style) connector on each end. The body of the circular connector is the ground conductor. A line-up guide is placed on each connector's end, and the retainer

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threads should be engaged for good contact. Figure 12 illustrates the circular connector with pins labeled.

- The Umbilical Cable is covered with a woven nylon mesh sheath to restrain the cable and reduce friction when moving the cable.
- The Umbilical Adapter connects the outlet of the last glass impinger train to the Umbilical Cable and contains the cold box exit thermocouple. This adapter serves as a strain relief between the Umbilical Cable and the glassware train.

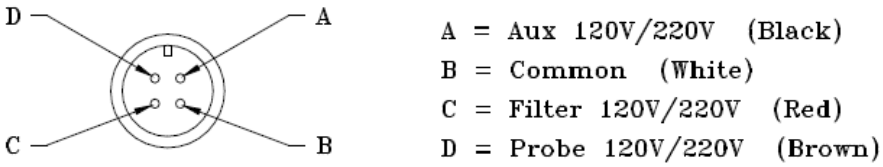

Figure 12 - Circular Connector and Electrical Pin Designations

GLASSWARE SAMPLE TRAIN

The sample glassware train contains the filter holder for collection of particulate matter, glass impingers for absorption of entrained moisture, and connecting glassware pieces. Figure 13 illustrates the glassware of the USEPA Method 5 sampling train. The order in which a typical USEPA Method 5 glassware train is constructed is as follows:

1. Cyclone Bypass (GN-1) *Optional*: Cyclone (GN-2) and Cyclone Flask (GN-3)
2. 3 inch Glass Filter Assembly (GNFA-3). Assembly consists of the Filter Inlet (GN-3S), Teflon Filter Disk or "Frit" (GA-3T), Filter Outlet (GN-3B), Filter Clamp (GA-3CA) and Glass Fiber Filter (GF-3 Series).
3. Double "L" Adapter (GN-8) or alternate GN-8-18K with thermocouple assembly
4. 1st Impinger Modified Greenburg-Smith (GN-9A)
5. U-Tube (GN-11)
6. 2nd Impinger Greenburg-Smith with Orifice (GN-9AO)
7. U-Tube (GN-11)
8. 3rd Impinger Modified Greenburg-Smith (GN-9A)
9. U-Tube (GN-11) 10. 4th Impinger Modified Greenburg-Smith (GN-9A)

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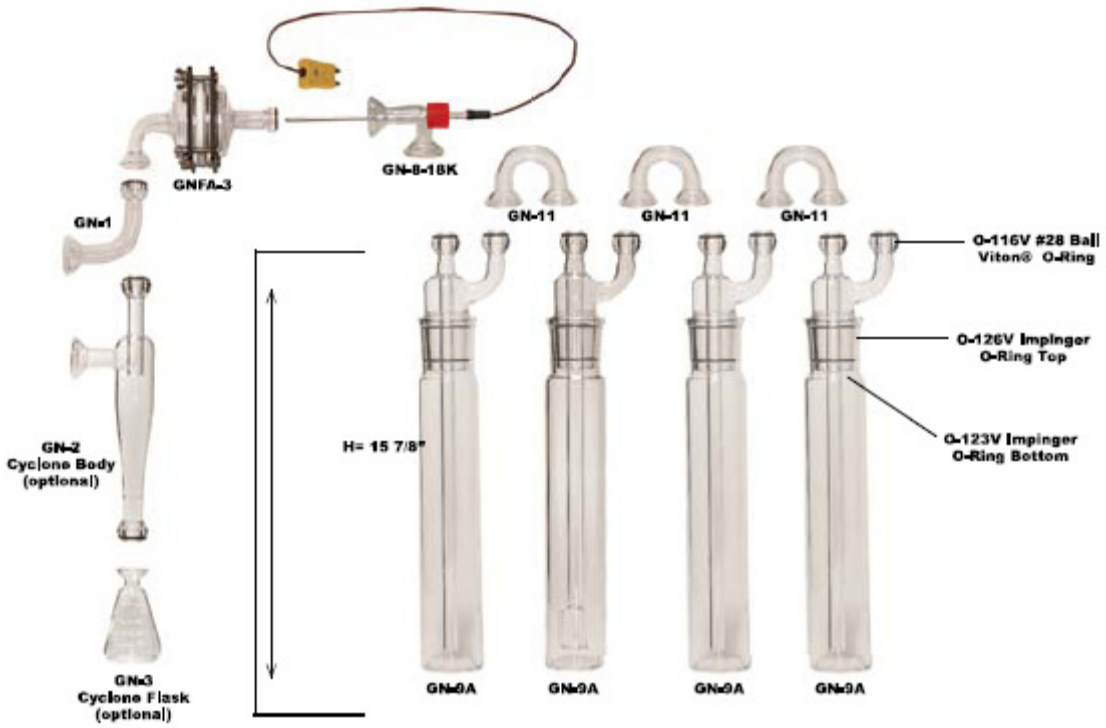

Figure 13 - Glassware Sampling Train Schematic

Operating Procedures

There are many elements to consider before testing for particulate matter, which includes:

- Set up and check of source sampling system,
- Test design,
- Site preparation,
- Sampling equipment calibrations (Described in Chapter 3),
- Assembling sampling equipment and accessories, reagents, sample recovery equipment, and sample storage containers, and
- Preliminary measurements of stack dimensions, gas velocity, dry molecular weight, and moisture.

Setup and Check of Source Sampling System

Carefully unpack the contents, saving the packing material until the parts have been examined for shipping damage and the sampling system has been completely assembled. Check each item against the packing list. If any item is damaged or missing, notify Apex Instruments immediately at 800-8823214 or email at info@apexinst.com. Appendix A lists the items in an Isokinetic Source Sampling System that are recommended for a system check.

INITIAL SET-UP PROCEDURE

These instructions are for a "dry run" set-up of the complete US EPA Method 5 sampling train. Do not load a glass fiber filter into the filter assembly, or charge liquids and silica gel in the impingers. The objective is to set-up the equipment to verify everything works.

1. Remove all items from packaging and place in an open area.
2. Slide the Impinger Case (Cold Box) onto the Modular Sample Case's heated filter compartment (Hot Box), using the steel slide guides. Check the fit and height of the Sample Case and Umbilical Adapter. The slides are adjustable for obtaining the desired fit. Engage the spring latch that locks the Cold Box into place.
3. Inspect the Probe Liner and Probe Assembly. Wipe clean the quick-connects on the Probe Assembly. A drop of penetrating oil helps keep the quick-connects in good working condition.
4. Slide the Probe Liner into the probe sheath. The plain end (no ball joint) of the liner should come out approximately 1.27-cm (1/2-inch) at the Pitot tube end of the Probe Assembly.
5. Insert and tighten the Probe Assembly into the probe clamp that is attached to the Hot Box. The outlet ball of the Probe Liner is carefully inserted through the hole into the Hot Box and the back of the sheath is even with the inside of the Hot Box.
6. Plug the Probe Heater electrical plug into the probe receptacle on the Hot Box.
7. To install a Nozzle to the Probe Assembly, consult Figure 14. Slide the ferrule system onto the plain exposed end of the Probe Liner. High temperature braided glass cord packing should be substituted for the o-ring when stack temperatures are >260°C (500°F). The Probe Assembly Spare Parts Kit (bag taped to probe sheath) contains fittings for two (2) different ferrule installation options: 1) Stainless Steel Single Ferrule, and 2) Backer Ring with O-Ring. The recommended configurations with different liner options are detailed below:
    a. Stainless Steel Liner Stainless Steel Single Ferrule, or Backer Ring with O-Ring
    b. Glass Liner Backer Ring with R-Ring, Teflon® Single Ferrule (Optional), Mineral-Filled Teflon® Single Ferrule (Optional).

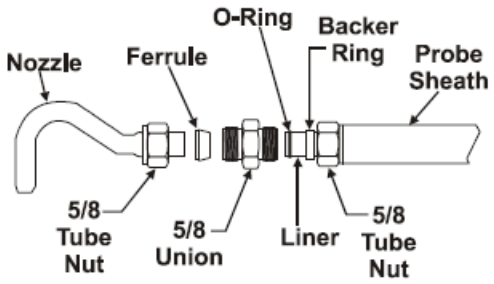

Figure 14 - Installation of Probe Nozzle Connectors

8. Thread the 15.875 mm (5/8-inch) union onto the nut welded to the probe sheath. This is a compression fitting which is tapered to seal the ferrule system inserted on the Probe Liner. Tighten the fitting until the liner has a leak-tight seal, but **DO NOT OVERTIGHTEN**.
9. Connect the glassware sampling train completely in the Hot Box and Cold Box, and tighten all joints using the Ball Joint Clamps. The final connection is the Umbilical Adapter, which slides into the clamp on the outside of the Cold Box. Do not load the Filter Assembly with a filter, and do not fill the impingers because this is a "dry" set-up.
10. Connect the Umbilical Cable to the Modular Sample Case. Connect the Umbilical Cable circular connector plug to the receptacle on the side of the Hot Box (see Figure 10). Connect the labeled Umbilical Cable thermocouple plugs into the receptacles on the Hot Box, Probe Assembly, and Umbilical Adapter. Insert the Umbilical Cable sample line female quick connect into the Umbilical Adapter male quick-connect.
11. Insert the Umbilical Cable female Pitot line quick-connects onto the Probe Assembly male quick-connects. Connect the Umbilical Cable to the Source Sampler Console. Connect the Umbilical Cable circular connector plug to the receptacle on the front panel of the Source Sampler Console. Connect the labeled Umbilical Cable thermocouple plugs into the receptacles on the Source Sampler Console front panel. Insert the Umbilical Cable sample line male quick connect into the Source Sampler Console female quick connect. Insert the Umbilical Cable Pitot line male quick connects onto the Source Sampler Console female quick connects (labeled + and -). The Pitot lines are colored to differentiate the positive and negative lines and keep the connections consistent between the Pitot tube and Source Sampler Console.
12. Connect the Vacuum Pump Assembly to the Source Sampler Console. Wipe the quick connects clean then connect the pressure and vacuum hoses on the Vacuum Pump Assembly to the pump connections located on the lower left of the Source Sampler Console front panel. Connect the power cord of the Vacuum Pump Assembly to the receptacle on the Source Sampler Console labeled PUMP.
13. Plug the Source Sampler Console into an appropriate electrical power source.
14. Perform a leak check as describe in XXXX.

TEST DESIGN

Before testing, the operator should know the following:

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- Why the test is to be conducted.
- Who will use the data.
- What stacks or emission points are to be tested and what process data is to be collected and correlated with test results.
- Where the sample ports are located and type of access.
- When the test is scheduled and deadlines for reporting.
- How the method or procedure is followed, and how many test runs or process conditions will be tested.

SITE PREPARATION

Preparing the site so that sampling equipment can be positioned is frequently the most difficult part of sampling. When the sample ports do not have a platform or catwalk, then scaffolding must be erected to reach the sampling site. At many sites the operator must use his ingenuity to get the sampling equipment to the sample ports. When selecting the site for sample ports, the operator should keep in mind that the distance from the probe to the bottom of the sample case is about 33 cm (13 ½ inches). This means that in traversing the stack, the sampling equipment needs 33 cm of clearance below the port level so as not to bump into guardrails or other structures. The dimensions needed for clearance along the sample port plane include the effective probe length (stack diameter plus port nipple length) **PLUS** at least 91 cm (36 inches) to accommodate the sample case (Hot Box, Cold Box, and probe clamp) length. Figure 15 illustrates the clearance zones required.

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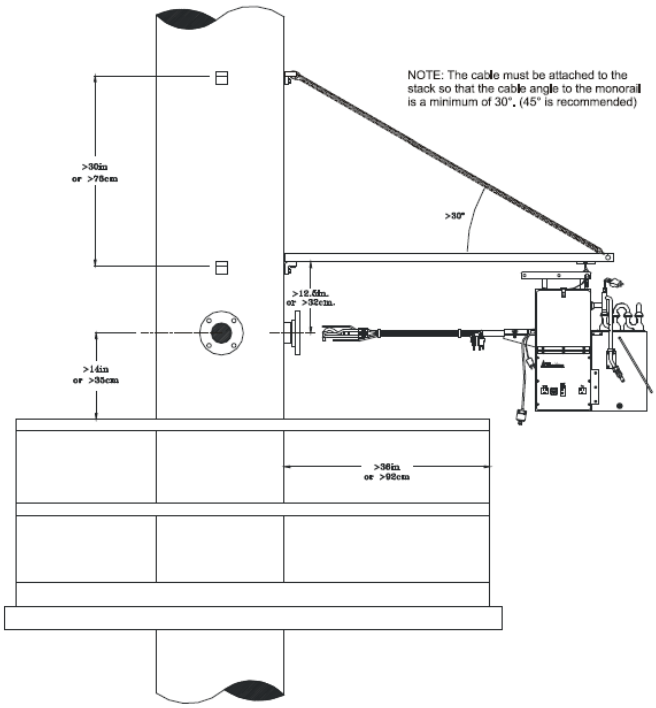

Figure 15 - Clearance Zones at Stack for Isokinetic Sampling Train

Where sampling train clearance problems cannot be overcome, Apex Instruments offers a non-rigid Method 5 sampling train with separate and/or miniature heated Filter Box (SB-2M) to allow the Cold Box to be placed on the sampling platform connected by the sample line and Umbilical Adapter (GA-104). Another option is to use the compact Method 5 with our Heated Filter Assembly (SFA-82H) and Power Box Adapter (UA-3J). Figure 16 illustrates the Non-Rigid Isokinetic Sampling Train.

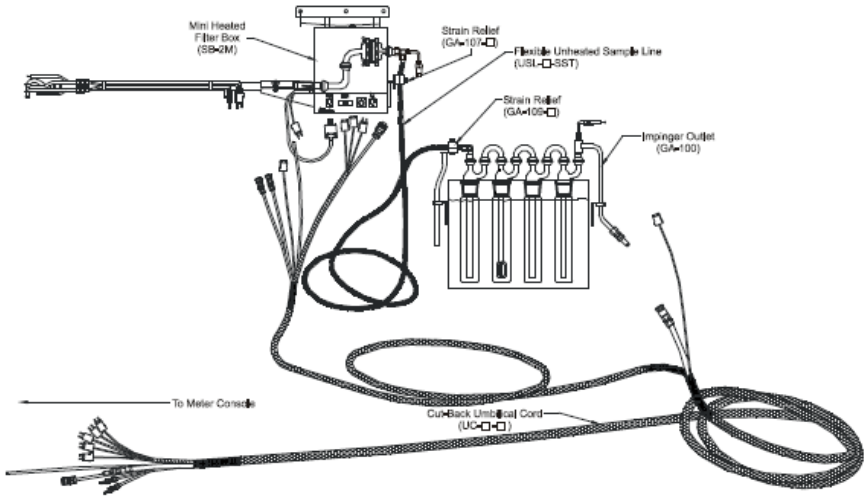

Figure 16 - Non-Rigid Isokinetic Sampling Train

The midget hot box allows for less clearance between the monorail and guardrail of the stack. Figure 17 illustrates the Compact Method 5. The small heated filter assembly allows greater flexibility in small sampling areas.

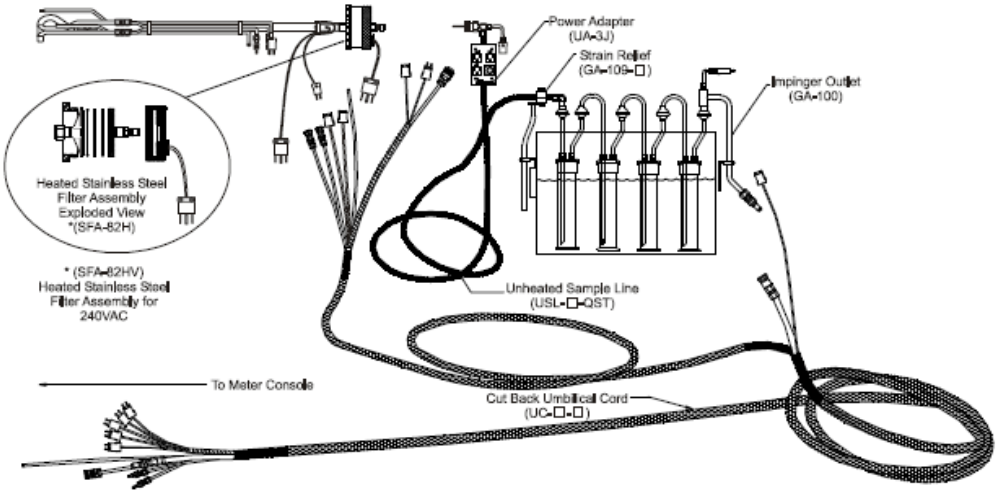

Figure 17 - Compact Isokinetic Sampling Train

Although the Isokinetic Source Sampling System was designed to fit into a 6.35 cm (2 ½ inch) sample port, 7.6 cm (3 inch) or larger holes allow easier entry and removal without damaging the nozzle or picking up deposited dust. There are basically two ways to mount the isokinetic sampling system (Hot Box/Cold Box) for testing on a stack:

1. Assemble a monorail system with lubricated roller hook above each sample port, or

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2. Construct a wooden platform slide apparatus (where feasible).

Monorail mounting can be accomplished when an angle iron, with a hole or an eyehook, has been welded to the stack. When no mounting support for a monorail system exists, this system can be easily installed using the Apex Instruments Monomount (P501) around the stack. Figure 18 illustrates an isokinetic sampling system mounted using the Apex Instruments Monomount (P501) monorail system above a sample port.

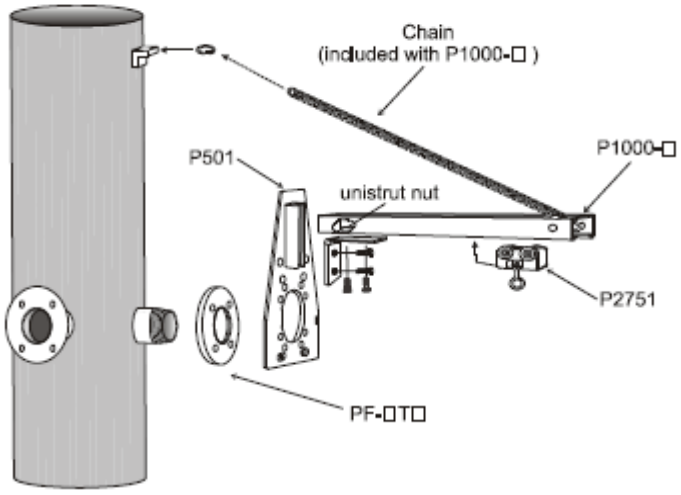

Figure 18 - Illustration of Apex Instruments Monomount Monorail System

Alternatively a tee bracket system, as shown in Figure 19 may be used, with the load bearing calculations described.

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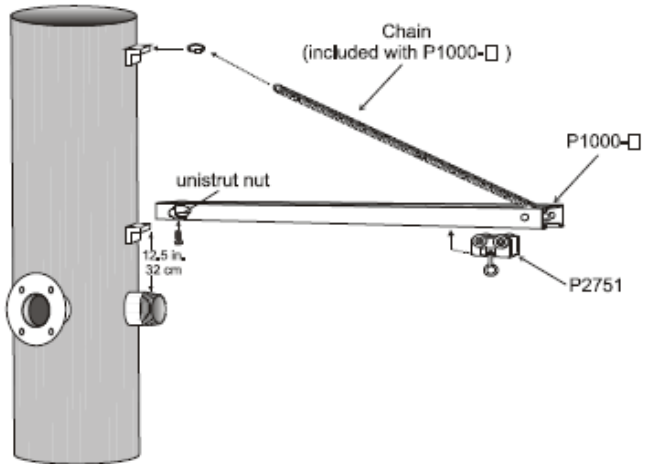

Figure 19 - Illustration of Monorail System for Sampling Train

Figure 20and Figure 21 illustrate a complete stack set-up using the Hot Box/Cold Box together (SB-1) and Hot Box and Cold Box separated (SB-2M and SB-3).

Figure 20- Stack Platform with Modular Sample Case on Monorail

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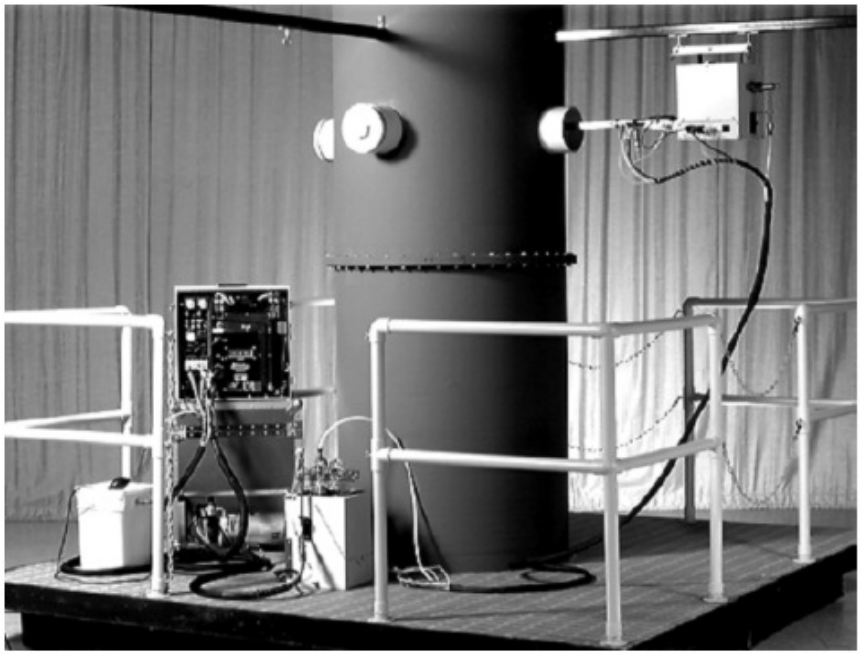

Figure 21 - Stack Set-up with Hot Box on Monorail Separated from Cold Box

ASSEMBLING SAMPLING EQUIPMENT AND REAGENTS

The use of checklists for assembling the sampling equipment, reagents and auxiliary supplies for a test is highly recommended. Appendix A contains the recommended equipment for isokinetic sampling. Appendix A also contains the recommended spare parts for isokinetic sampling, although not all of the list may be needed at a test site. Section 3 of USEPA Method 5 contains the list of reagents required to perform an isokinetic particulate test. A standard equipment and reagent checklist used by stack testers is provided in Appendix A.

Preliminary Measurements of Gas Velocity, Molecular Weight and Moisture

Before attempting to calculate the parameters needed for isokinetic sampling – probe nozzle size, ratio of ΔH/ΔP (K factor) needed for isokinetic sampling rate, gas sample volume – several preliminary values are required:

Table 8 - Preliminary Measurements for Isokinetic Sampling

No.	Symbol	Value Needed	Obtain from

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1.	Δp_{avg}	Average stack gas velocity pressure head	1. Before the sample run (best), or 2. A previous test (often erroneous)
2.	P_s	Stack gas pressure	1. Before the sample run (best), or 2. A previous test (very small error)
3.	P_m	Dry Gas Meter Pressure	Same as Barometric Pressure
4.	B_{ws}	Stack gas moisture fraction	1. Before the sample run (best), or 2. A previous test (often erroneous)
5.	T_s	Average stack gas temperature	3. Before the sample run (best), or 4. A previous test (often erroneous)
6.	T_m	Average dry gas meter temperature	Meter temperature rises above ambient because of pump heat and is typically estimated at 14°C (2°F) above ambient
7.	M_d	Stack gas molecular weight	1. Before the sample run (best), or 2. A previous test (very small error)
8	ΔH@	Orifice meter calibration factor	Determined previously from laboratory calibration

Conducting a Test

The XC-5000 Source Sampling System has been designed and developed to perform a test following USEPA stationary source testing methodology. The XC-5000 software design considers each individual sample run comprising one or more traverse points and traverse lines as a single “Test”.

The hardware and software work together to guide the user through the entire test process including Methods 1 through 4, necessary for gathering the preliminary values for Method 5 sampling, all associated system leak checks, sensor calibration/audits and then performing the Method 5 test.

It is vitally important that the system operator follow the Console’s menu structure in order to carry out a valid test in conformance with USEPA method requirements. By accurately completing required user input data and conducting the test according to method protocols, the XC-5000 ensures the completion of a valid test run.

During the conduct of the test, the software performs all required calculations and automatically monitors the status of all system sensors and operating parameters and also provides operator prompts, for example, when to change the test point location.

Each test results in a test run specific data file (.CSV format) containing all required preliminary values including user desired test and site identification details, quality control checks, sensor parameter data.

As mentioned previously, the User Interface software menus have been constructed to follow the logic and steps used in the USEPA's source testing methods. Any and all necessary calculations in the methods are normally performed automatically by the XC-5000 User Interface software and operating system firmware. Please note that the User Interface does allow the user the opportunity to override the automatic calculations but may not accept an override if it doesn't meet validity criteria programmed into the software. Also, the User Interface provides the opportunity for a user to bypass the automatic calculation if the user can supply the appropriate final calculated value. These features will be evident as the test is configured and carried out.

This chapter has been divided into several sections detailing each part of the test process:

1. Establish Communications
2. Complete Job Info
3. Attach Pre-Test Console Audit
4. Complete Other Pre-Test Data
5. Complete Method 1
6. Complete Method 2
7. Calculate Nozzle Size
8. K Factor Determination and Configuration
9. Perform Pre-Test Leak Check
10. Conduct Sample Traverse
11. Perform Post-Test Leak Checks

Where appropriate, the operational details, requirements and calculations underpinning Methods 1 – 5 have been retained in the following sections to provide background on what is being performed by the instrument when a test is being conducted.

1. Establish Communications

a) Start the XC-5000 software on your computer.

b) Connect an Ethernet cable between your computer and the XC-5000 Console. Once the software is running and the cable is connected, establish communications between the XC-5000 by clicking the 

button on the Main Menu (see below).

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Figure 22 - Main Menu Before Establishing Communications

c) When communications have been established, the text on the Connect button label will change to Disconnect. Also, the Main Menu will show the current date and time in the upper left-hand portion of the menu.

2. Complete Job Info

a) To start a new test file, click the New Project button. To use an existing test profile, click the Load Project button.

b) Next, click the Job Info. button to open the Job Info Menu.

This menu, shown in Figure 23, below, contains data entry fields for Plant Name, Sampling Location, Project / Job # and Notes. These fields can accept any alphanumeric characters. Any data entered is stored in the test data file to provide for information in a test report.

c) Select the appropriate radio button to choose the reporting units in either English Units or in Metric Units. This choice determines the configuration of units used in all calculations, sensor information displays and measurement data.

d) Verify the values for Standard Pressure and Standard Temperature. The default values supplied by the program are those specified in the USEPA Source Emissions Reference Methods. The user may modify the values by entering new values in the respective fields.

e) When all data have been entered, click the Accept button to accept data entered into this menu form and return to the Main Menu.

Notes: When any data have been entered, the Accept button will become active. The Save Project button the Main Menu can be clicked at any time to store data entered into any menu. It is good practice to click the Save Project after completing each menu.

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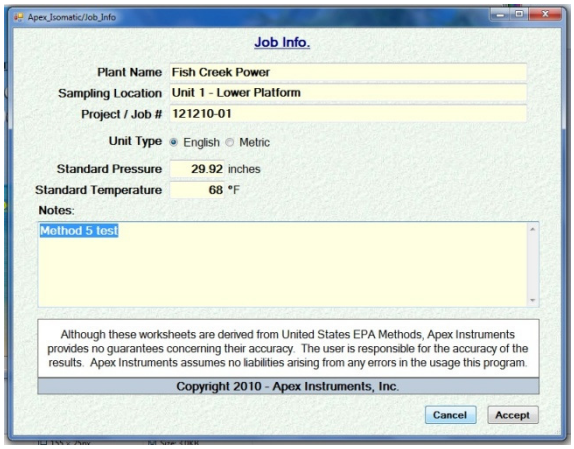

Figure 23 - Job Information Menu Scren

3. Attach Pre-Console Audit

The Pre-Console Audit Menu allows the operator to attach the data compiled during a previously conduct system audit.

a) Click the Get Pre-Console_Audit File button depicted in the Pre-Console Audit menu, Figure 24, below, to attach an Audit data file to the current test file. The Audit file will be attached to the test record when the Accept button on this screen is clicked and the program will return the user to the Main Menu.

b) The program will return the user to the Main Menu.

Note: If the Accept button is not active, no Pre-Console Audit file has been selected. Exit this screen and return to the Main Menu by clicking the Accept button.

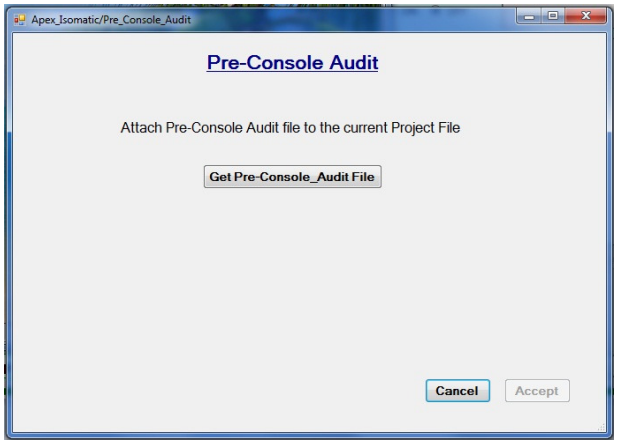

Figure 24 - Pre-Console Audit Menu Screen

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Note: The Pre-Console Audit is generally performed in the laboratory or instrument shop prior to transporting the system to the test site. Instructions for conducting the audit are provided in Chapter XX - System Audits, Calibration and Maintenance.

4. Complete Other Pre-test Data – Method 3 and Method 4

This **Other Pre-Test** Data menu is used to enter data for stack gas composition in order to calculate the stack gas dry molecular weight and for the water content of the stack gas. This menu also includes fields for entering the desired set points for the Probe and Oven/Filter Heaters.

The program offers two options for entering Method 3 data. The program can either automatically calculate the Dry Molecular weight using the data in the input fields that is supplied from data determined previously using Method 3. Or, if known, directly enter the Dry Molecular Weight value in its field. If the user enters data for each gas parameter, the program calculates the Dry Molecular Weight when the cursor is placed in the Dry Molecular Weight field. If the user directly enters the Dry Molecular Weight into its field, the program will use that value for subsequent calculations.

To complete the Other Pre-Test Data:

a) From the Main Menu, click Other Pre-Test Data button. The menu is shown in Figure 25, below.

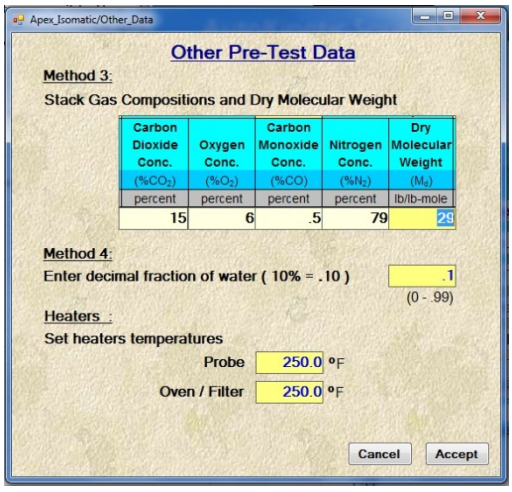

Figure 25 - Other Pre-test Data Menu Screen

b) Enter the decimal fraction of water determined using Method 4.

c) Enter the desired heater temperature set points for the Probe.

d) Enter the desired heater temperature set point for the Oven / Filter.

IMPORTANT: Any data entry field with a yellow background indicates that field must be completed in order to continue.

A discussion of the methods used to determine stack gas molecular weight and stack gas moisture content follows.

Discussion – Background Information on the Determination of Stack Gas Molecular Weight and Moisture Content

The stack gas molecular weight dry basis (M_d) is corrected to the wet basis (M_s) using the moisture fraction (B_{WS}) by the equation:

$$M_s = M_d - B_{WS} + 18.0B_{WS}$$

After the average stack gas velocity (V_s) has been calculated, the volumetric flow rate can be calculated. The area of the stack (As)is calculated for circular stacks as:

$$A = \pi\left(\frac{\mathbf{D_s}}{2}\right)^2$$

For rectangular stacks:

$$A = \mathbf{LW}$$

The stack gas volumetric flow rate is calculated using the following equations:

$$Q_a = 60 v_s A_s$$

$$Q_a = K_s v_s A_s \frac{P_s}{T_s}$$

$$Q_{std} = K_s(1 - B_{WS}) v_s A_s \frac{P_s}{T_s}$$

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Where Q_a = Volumetric flow rate, actual, m/min (acfm)

Q = Volumetric flow rate, standard, sm_3/min (scfm)

Qstd = Volumetric flow rate, dry standard, $dsmm^3$/min (dscfm)

K = Constant to convert time to minutes and P/T to standard conditions

= 21.553 for metric units (1058.8 for English units)

Discussion – Method 3 – Gas Analysis for Dry Molecular Weight – Description and Background Information

Method 3 is used to measure the percent concentrations of carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) if greater than 0.2%. Nitrogen (N_2) is calculated by difference. From this data, the stack gas dry molecular weight, or density, is calculated, and this data is used in the equation for stack gas velocity. From the gas composition data, the amount of excess air for combustion sources can be calculated. In jurisdictions where the particulate emissions are regulated on a concentration basis, such as mg/m^3, the gas composition data can be used to correct the concentration results to a reference diluent concentration, for example 7% O_2 or 12% CO_2. There are three options for determining dry molecular weight:

1. Sample and analyze,
2. Calculate stoichiometrically for combustion sources the O_2 and CO_2 concentrations, or
3. If burning fossil fuels (Coal, oil or natural gas), assign a value of 30.0 for dry molecular weight.

The stack gas sample can be collected using one of three options:

1. Grab sampling from a single traverse point a portion of the stack gas using a one-way squeeze bulb and loading directly into the analyzer. This technique can also be used to measure gas composition at individual traverse points to determine if stratification exists.
2. Integrated sampling from a single traverse point into a flexible leak-free bag. This technique recommends collection of at least 30 liters (1.00 cu. ft.); however, smaller volumes may be collected if desired. Constant rate sampling is used.
3. Integrated sampling from multiple points in a flexible leak-free bag. This technique is used when conducting a Method 5 particulate traverse and using the Orsat gas collection line built onto the Probe Assembly. Sample volume and rate recommendations are the same.

Gas samples can be analyzed using either an Orsat or Fyrite analyzer. Figure 26 depicts the options for sample collection and analysis.

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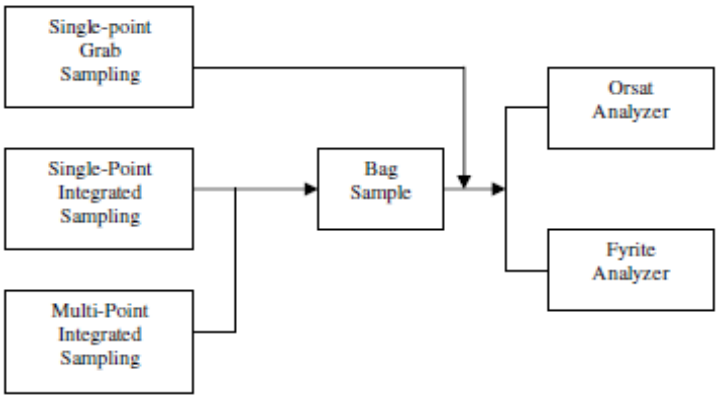

Figure 26 – Method 3 Sampling and Analysis Options

Both the Orsat Analyzer and a Fyrite Analyzer are gas absorption analyzers, and measure the reduction in liquid volume when a gas sample is absorbed and mixed into a liquid solution. The Fyrite Analyzer uses separate gas absorption bulbs for O2 and CO, while the Orsat Analyzer (Model VSC-33) contains all three absorption bubblers for O2, CO2 and CO in a single analyzer train. The Orsat provides a more accurate analysis of gas composition, and is required by Method 3B when pollutant concentration corrections are made for regulatory purposes. Figure 27 illustrates an Orsat Analyzer connected to a bag sample collection enclosure. The CO concentration is typically not measured by the Orsat analyzer for two reasons.

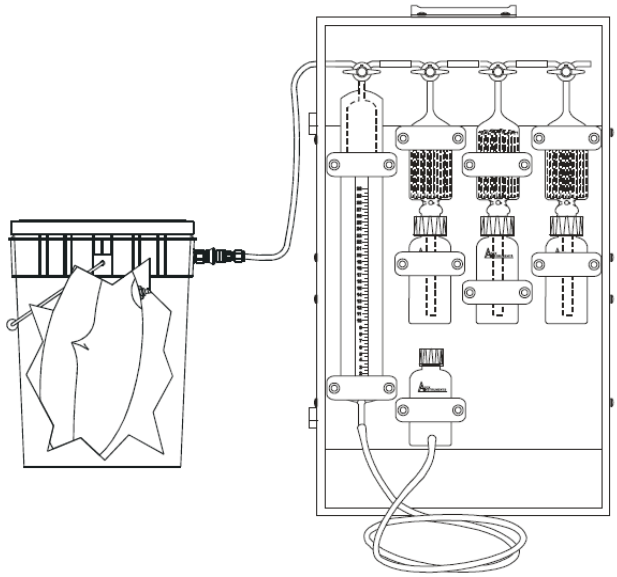

Figure 27 - Illustration of Orsat Analyzer and Gas Sample Bag Container

First, the detection limit of the analyzer is 0.2% by volume (2,000 ppmv) which is well above most modern combustion source CO concentrations. Second, the molecular weight of CO is the same as N_2 (28 g/g-mole) and the balance of gas can be assumed to N_2 without any change in calculation of molecular weight. For a more detailed discussion of gas analysis using an Orsat Analyzer, please refer to Apex Instruments' *Combustion Gas (ORSAT) Analyzer, Model VSC-33, User's Manual and Operating Instructions,* or the operating instructions provide with the Fyrite Analyzer.

The equation used to calculate dry molecular weight of a stack gas is:

$$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2) + \%CO$$

Where, %CO = Percent CO_2 by volume, dry basis

%O_2 = Percent O_2 by volume, dry basis

%N_2 = Percent N_2 by volume, dry basis

%CO = Percent CO by volume, dry basis

0.28 = Molecular weight of N_2 or CO, divided by 100

0.32 = Molecular weight of O_2, divided by 100

0.44 = Molecular weight of CO_2, divided by 100

Discussion – Method 4 – Moisture Content of Stack Gas – Description and Background Information

There are two separate procedures for determining moisture content in stack gases:

- The first is a Reference Method, for accurate measurements of moisture such as are needed to calculate emission data, and
- The second is an approximation method, which measures percent moisture to a good enough estimate to aid in setting isokinetic sampling rates prior to a pollutant emission run.

The approximation method is only a suggested approach. Alternative ways for approximating moisture content are also acceptable, for example:

- Wet bulb/dry bulb techniques (applicable to gas streams less than 100° C),
- Stoichiometric calculations (applicable to combustion sources),
- Condensation techniques,

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- Drying tubes, and
- Previous experience testing at a stack

The Reference Method is almost always conducted simultaneously with a pollutant emission measurement run. The Reference Method is also used when continuous monitoring for pollutants, such as SO_2, NO_x or O_2 need to be corrected to a dry basis. The equipment set-up for the Reference Method can consist of either of these sampling trains:

- The isokinetic source sampling system (Hot Box and Cold Box) equipped with Probe Assembly with no nozzle, and a filter bypass (GN-13) piece of glassware instead of a Filter Assembly (filter may be used if particulate levels are high), or
- The Basic Method 4 Test Kit includes a Cold Box, Sample Frame with Probe Clamp (SB8), and Umbilical Adapter with power connector (GA-103), as shown in Figure 28. Either a standard heated Probe Assembly or a heated CEM probe (no Pitot tube) can be used.

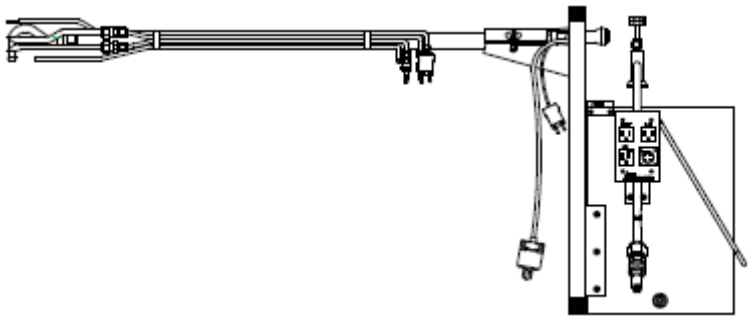

Figure 28 - Set-up of Cold Box with Sample Frame and Probe Clamp

Although glass impingers are typically used as the condenser section in Method 4 and other isokinetic methods, they can be replaced with a stainless steel equivalent coil condenser (S-4CN) making a rugged and reliable system without the fragility of the traditional glass assembly.

Accurate Method (Method 4)

Use the following procedure for accurate measurements of moisture content:

Preparation

a. Use at least the following number of traverse points and locate them according to Method 1
    i. 8 for circular ducts <60 cm (24 inches) diameter
    ii. 9 for rectangular ducts <60 cm (24 inches) equivalent diameter
    iii. 12 for all other cases
b. Transfer about 100 ml of water into the first two impingers. Leave the third impinger empty, and weigh each impinger to ± 0.5 g.

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c. Transfer about 200-300 g of silica gel into the fourth impinger, and weigh to ± 0.5 g.

d. Determine the sampling rate to collect = 0.741 sm (21scf) at = 21 lpm (0.75 cfm) simultaneously with the pollutant emission rate test run (and for the same length of time).

e. If the gas stream is saturated or contains moisture droplets, attach a temperature sensor (± 1.3° C) to the probe or check the saturation moisture at the measured stack temperature. *See Section D.*

2. Sampling

a. Assemble and set up the sampling train.

b. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F). Allow time for the temperatures to stabilize. Place crushed ice in the ice bath container (Cold Box) around the impingers.

c. ***Optional:*** Leak-check the sampling train from the inlet of the first impinger or, if applicable, the filter holder (see Leak-Check Procedure).

d. Position the probe tip at the first traverse point. Sample at a constant (± 10%) flow rate. Record data on a field data sheet.

e. Traverse the cross-section, sampling at each traverse point for an equal period of time.

f. Add more ice and, if necessary salt to maintain = 20° C (68° F) at the silica gel impinger exit.

g. After the last traverse point of the cross-section, turn off the sample pump, switch to the next sample port, and repeat steps 2D through 2F.

h. At the completion of sampling, disconnect the probe from the first impinger (or from the filter holder).

i. ***Mandatory:*** Leak-check the sampling train as in step 2c.

3. Sample Recovery

a. Disassemble the impinger glassware and weigh each impinger to ± 0.5 g. Record weighing data on a field data sheet.

b. Verify constant sampling rate.

c. Calculate the stack moisture percentage.

4. Saturated or Moisture Droplet-laden Gases

a. Measure the stack gas temperature at each traverse point. Calculate the average stack gas temperature.

b. Determine the saturation moisture content by: a) using saturation vapor pressure tables or equations, or b) using a psychrometric chart and making appropriate corrections if stack pressure is different from that of the chart.

c. Use the lower of this value or the value from Section C.

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Tips from an Old Stack Tester

Make sure to wipe off moisture from the outside of each impinger before weighing. Do not weigh with U-tubes connected.

Approximation Method

The Method 4 approximation method specifies use of midget impingers and a Source Sampler Console sized for midget impinger trains, such as that used for Method 6 for SO_2. Many stack testers perform preliminary moisture measurements for input to their isokinetic calculations nomograph by using a full-size sampling train and collecting about 0.283 sm^3 (10scf) of gas sample. These runs take about 15 to 20 minutes. Use the following procedures for approximate measurements of moisture content:

Midget Impinger Train

1. Preparation
    a. Transfer about 5ml of water into each impinger (2), and weigh each impinger to ± 0.5 g. Assemble the sampling train.
    b. Connect a pre-weighed drying tube to the back of impinger train.
2. Sampling
    a. Assemble and set up the sampling train.
    b. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120°C (248°F). Allow time for the temperatures to stabilize. Place crushed ice in the ice bath container (Cold Box) around the impingers.
    c. ***Optional:*** Leak-check the sampling train from the inlet of the first impinger inlet or, if applicable, the filter holder (see Leak-Check Procedures for nonisokinetic or isokinetic sampling trains).
    d. Position the probe tip well into the stack. Sample at a constant (± 10%) flow rate of 2 lpm until about 0.031 m^3 (1.1 cf) or until visible liquid droplets are carried over from the first impinger to the second. Record initial and final data on a field data sheet.
    e. Add more ice and, if necessary salt to maintain = 20° C (68° F) at the silica gel impinger exit.
    f. ***Mandatory:*** Leak-check the sampling train as in step B3.
3. Sample Recovery
    a. Disassemble the impinger glassware and weigh each impinger or drying tube to ± 0.5 g. Record weighing data on a field data sheet.
    b. Verify constant sampling rate.
    c. Calculate the stack gas moisture percentage.

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Large Impinger Train

1. Preparation
    a. Transfer about 100ml of water into the first two impingers. Leave the third impinger empty, and weigh each impinger to 0.5 g.
    b. Transfer about 200-300 g of silica gel to the fourth impinger, and weigh to 0.5 g.
2. Sampling
    a. Assemble and set up the sampling train.
    b. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120°C (248°F). Allow time for the temperatures to stabilize. Place crushed ice in the ice bath container (Cold Box) around the impingers.
    c. ***Optional:*** Leak-check the sampling train from the inlet of the first impinger inlet or, if applicable, the filter holder (see Leak-Check Procedures for non-isokinetic or isokinetic sampling trains).
    d. Position the probe tip well into the stack. Sample at a constant (± 10%) flow rate of = 21 lpm (0.75 cfm) until about 0.283 m^3 (10 cf). Record initial and final data on a field data sheet.
    e. Add more ice and, if necessary salt to maintain = 20° C (68° F) at the silica gel impinger exit.
    f. ***Mandatory:*** Leak-check the sampling train as in step B3.
3. Sample Recovery
    a. Disassemble the impinger glassware and weigh each impinger or drying tube to ± 0.5 g. Record weighing data on a field data sheet.
    b. Verify constant sampling rate.
    c. Calculate the stack gas moisture percentage.

To calculate the stack gas moisture content (B_{WS}), the following equations are used to compute the sample gas volume ($V_{m(std)}$) and gas moisture volume ($V_{wc(std)}$)*:*

$$V_{m(std)} = K_3 Y \frac{V_m \left(P_{bar} + \frac{\Delta H}{13.6}\right)}{T_m}$$

where Δ H = Average orifice tube pressure during sampling, mm H2O (in. H2O)

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V = Dry gas volume measured by dry gas meter, dcm (dcf)

Tm = Absolute temperature at dry gas meter, ° K (° R)

Y = Dry gas meter calibration factor

K = 0.3858 °K mm Hg (Metric units)

=17.64 ° R/in. Hg (English Units)

$$W_f - W_i$$

Where, W_f =Final weight of water collected, g

W_i = Initial weight of water collected, g

K_2 = 0.0013365 m3/g (Metric units)

= 0.04715 ft^3/g (English units); and

$$B_{ws} = \frac{V_{wc(std)}}{V_{m(std)} + V_{wc(std)}}$$

Where, B_{ws} = Proportion of water vapor, by volume, in the gas stream.

5. Method 1 – Determining Sample Velocity Traverse Points

Method 1 is the first step towards collection of a representative sample for measuring particulate concentration and mass emission rate from a stack. The velocity and particle concentration in the stack are not uniform, so the cross-section must be traversed. The basic premise is that for straighter lengths of stack or duct, flow streamlines are more uniform and fewer traverse points are needed to obtain a representative sample. Conversely, the closer the sampling site is to bends and flow disturbances, the more traverse points are needed to obtain a representative sample. This method describes procedures to:

- Select an appropriate sampling location on the stack (if sample ports do not already exist)
- Calculate the number of traverse points for velocity and particulate sampling within the stack
- Calculate the location of the traverse points

Sampling sites are measured in terms of number of stack or duct diameters away from flow disturbances. Disturbances can be bends, transitions, expansions, contractions, stack exit to atmosphere, flames or presence of

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internal installations such as valves or baffles. Figure 29depicts the relationship of stack diameters and a flow disturbance such as a bend.

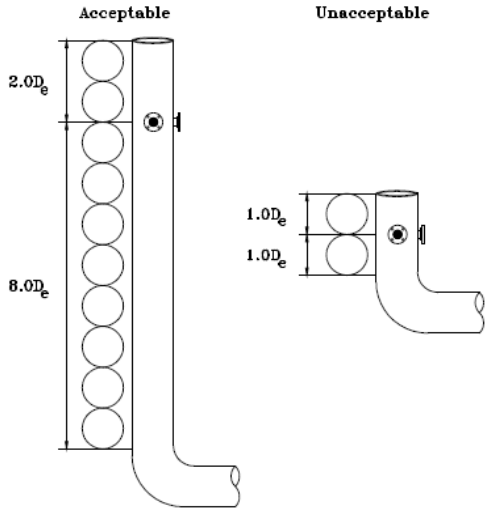

Figure 29 - Visualizing Stack Diameters from Flow Disturbances

The procedure for determining the minimum number of traverse points is as follows:

a) Measure the stack diameter to within 0.3175 cm (1/8 inch)
   i) Insert a long rod or Pitot tube into the duct until it touches the opposite wall.
   ii) Mark the point on the rod where it meets the outside of the port nipple. 3) Remove the rod, measure, and record this length to the far wall, L_{fw}.
   iii) With a tape measure (or rod if stack is hot), measure the distance from the outside of the port nipple to the near wall and record this length to the near wall, L_{nw}.
   iv) Calculate the diameter of the duct from this port as $D = L_{fw} - L_{nw}$.
b) Repeat for the other port(s) and then average the D values.
c) Measure the distance from the sample port cross-sectional plane to the nearest downstream disturbance (designated Distance A).
d) Measure the distance from the sample port cross-sectional plane to the nearest upstream disturbance (designated Distance B).
e) From the XC-5000 User Interface Main Menu, click the Method 1 button. The top portion of this menu is shown in

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Note: This menu is not fully displayed. To access all information and fields, click and drag the scroll bar control on the right hand side of the window.

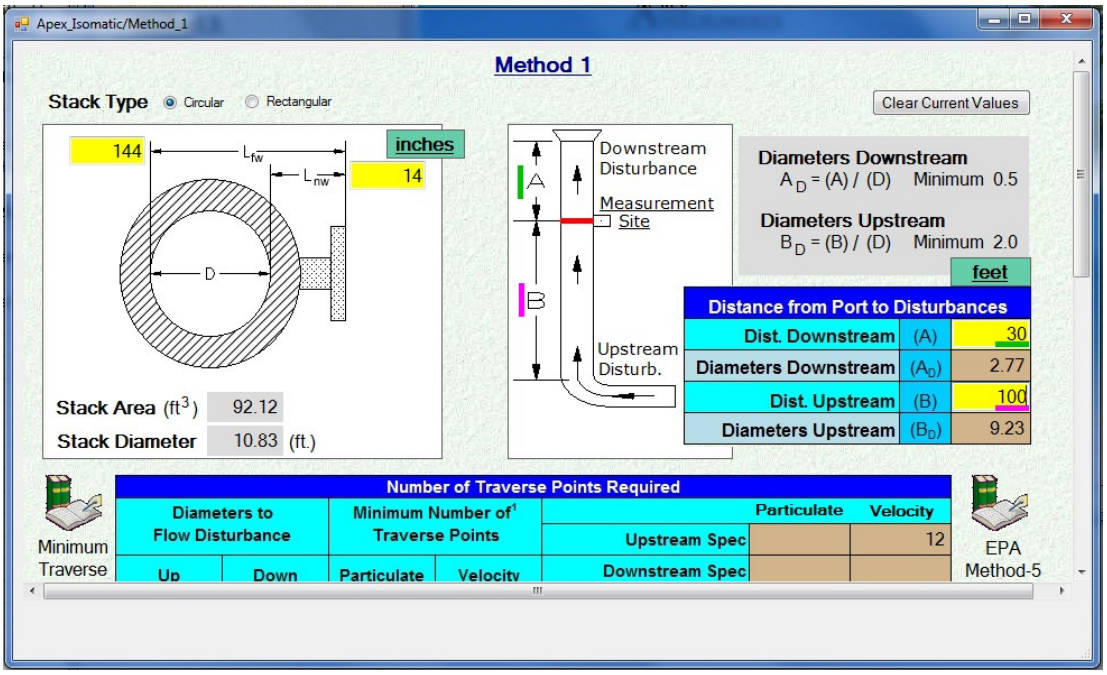

Figure 30 - Top Section of Method 1 Menu Screen

f) If any data are already displayed in this menu's user input fields, it can be modified by either entering the new value in each field or by clicking the Clear Current Values button to clear all fields in this form.

g) Select the Stack Type (Circular or Rectangular) by clicking on the appropriate radio button.

h) Enter the length from the far inside wall of the stack to the port flange face (L_{fw}).

Note: Be sure to enter data in the appropriate units of measure as shown on the labels next to the data input fields.

i) Enter the length from the near inside wall of the stack to the port flange face (L_{nw}).

j) Enter the distances to the Downstream and Upstream Disturbances.

The XC-5000 software will then calculate the stack area, the stack diameter, and the number of diameters to the upstream and downstream disturbances. If the distances to either the upstream or downstream disturbances do not meet the "8 and 2" criteria given in Method 1, the user input field for the distance will turn red signifying that additional traverse points over the minimum requirement are necessary in order to meet Method 1 sampling requirements.

k) Use the mouse wheel or scroll bar to scroll down the menu to access the input fields for **Test Parameters**. This section of the Method 1 Menu is shown in , below.

l) Click on the user input field for the Number of Ports and either enter the number of ports or click the drop down box arrow and select the desired number of ports from the list.

m) Click on the Number of Traverse Points (Per Port) and enter the number of traverse points to be sampled from each port or click the drop down box arrow and select the desired number of points from the list. A table showing the required number of points required points per USEPA Method 1 is displayed in the panel immediately above the **Test Parameters** and **Order of Traverse Points** panels.

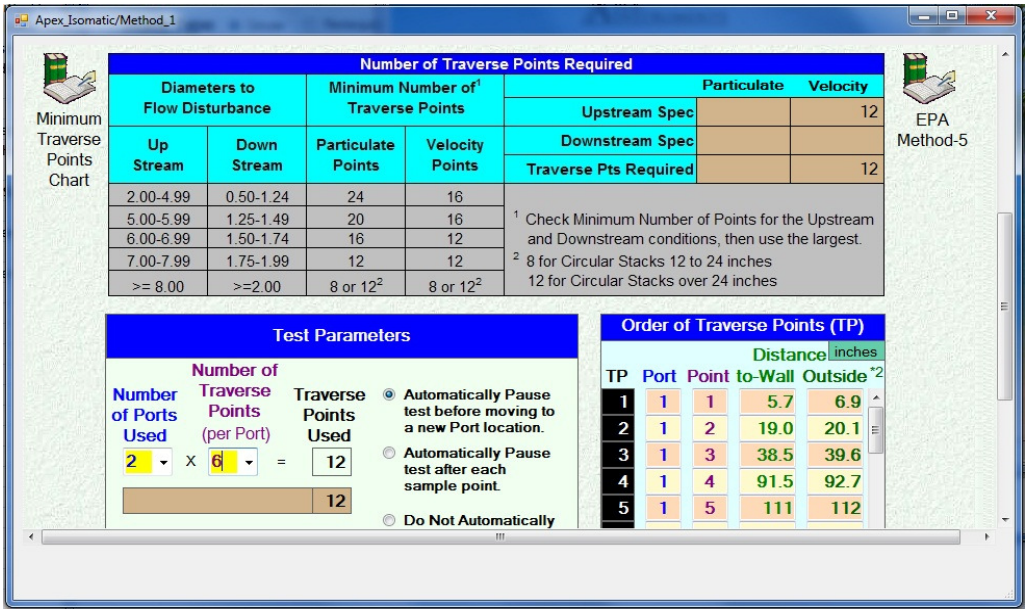

Figure 31 - Mid-Panel Method 1 Menu Screen

n) Scroll to the bottom of the screen to access the remainder of user input fields this menu (see Figure 32, below.)

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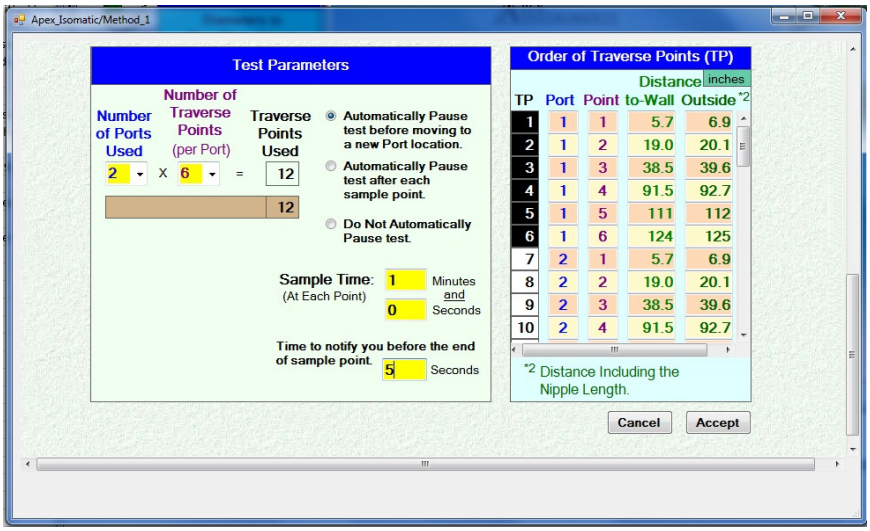

Figure 32 – Bottom Section - Method 1 Menu Screen

o) The system can be configured to pause sampling (turns the pump off) between port changes, between point changes or not to pause. Click the appropriate radio button in the **Test Parameters** panel to choose the desired setting.

p) Enter the desired length sampling time at each point (in minutes and seconds)in the **Test Parameters** panel. The total sampling time (number of traverse points multiplied by minutes/point) as well as the final estimated gas sample volume ($V_{m(std)}$) should be checked against any applicable environmental regulations for the industry to see if minimum sampling times and volumes will be acceptable. The calculation may involve some iterations in selecting K-factors and/or nozzle size that will yield acceptable sampling volume and time. Select the total sampling time and standard gas sample volume specified in the test procedures for the specific industry. Select equal sampling times of = 2 minutes per traverse point.

q) Enter the length of time you wish to be notified in advance of each sample point change in the **Test Parameters** panel.

r) Mark the probe as indicated in the **Order of Traverse Points (TP)** panel. Note that you will have to scroll down this panel to access complete traverse point information.

s) When all entries in the Method 1 Menu have been completed, click Accept to store the data in the program and return to the main menu.

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All input information is then used to determine the locations for velocity traverse and particulate traverse points in accordance with the USEPA Method 1 protocols.

Tips from an Old Stack Tester

- *Measure the stack diameter from each sampling port – not all circular stacks are round! And not all rectangular stacks are perfectly rectangular.*
- *By Measuring in each port, we can often find in-stack obstructions and can check ourselves against erroneous measurements.*
- *If possible, shine a flashlight across the stack and check for obstructions or irregularities.*
- *If possible, with a glove on your hand, reach into the sampling port and check that the port was installed flush with stack wall (does not extend into the flow.)*

Discussion – Method 1 Description and Background Information

An explanation of how the program determines the sample locations follows.

Figure 33 illustrates determining the total traverse point number from the curve of Figure 1-1 in USEPA Method 1. For example, if Distance A is 1.7 duct diameters and Distance B is 7.5 duct diameters, then Distance A would indicate use of 16 traverse point and Distance B would indicate use of 12 traverse points. You must choose the higher of the two. Therefore, the sampling site requires 16 total traverse points, eight in each of two directions 90° apart .

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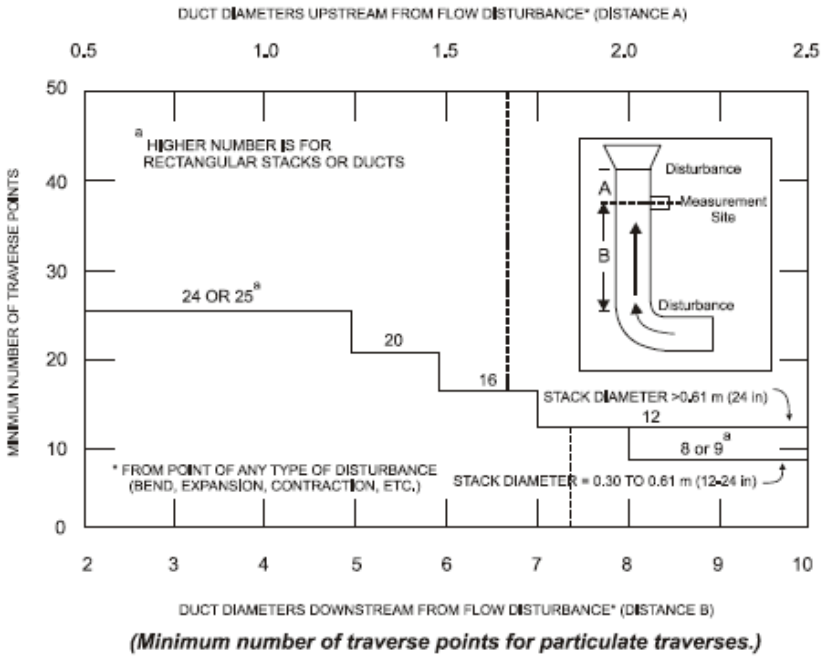
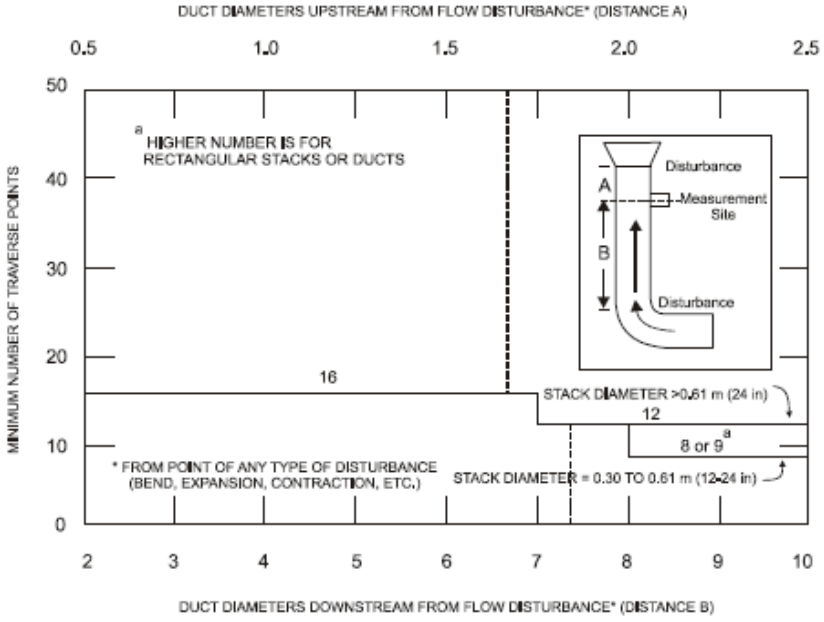


(Minimum number of traverse points for particulate traverses.)



(Minimum number of traverse points for non-particulate traverses.)

Figure 33 - Example of Number of Traverse Points for Particulate and Non-Particulate Traverses

For circular stacks with diameters greater than 60 cm (24 inches), the minimum number of traverse points required is twelve (12), or six (6) in each of two directions 90° apart, when the duct diameters from disturbances are eight (8) or more upstream and two (2) or more downstream. For circular stacks with diameters between 30 and 60 cm (12 and 24 inches), the minimum number of sample points required is eight (8), or four (4) in each of two directions 90° apart. For stacks less than 30 cm (12 inches) in diameter, refer to Method 1A for calculating traverse points. For rectangular stacks or ducts, an equivalent diameter must first be calculated using the following equation:

$$D_e = \frac{2LW}{L+W}$$

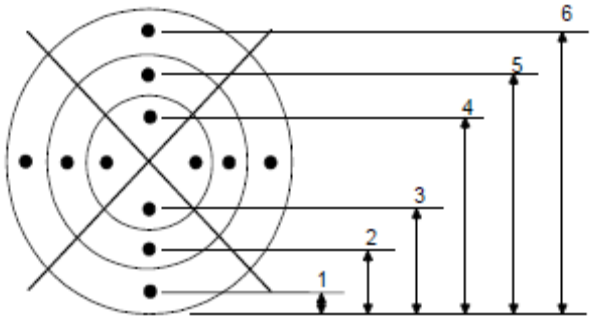
where, D_e = equivalent diameter of rectangular stack

L = length of stack

W = width of stack

The minimum number of traverse points required for rectangular stacks is nine, or 3 x 3. After the number of traverse points has been determined, the location of each traverse point must be calculated. The traverse points and their locations are designated as the sample point matrix. For circular stacks, the stack cross-section is divided into concentric rings of equal area based on the number of traverse points divided by four (4), the rings are bisected twice, and the sample points are located in the centroid (center of mass of each equal area, as shown in Figure 34.

TRAVERSE POINT	DISTANCE % of diameter
1	4.4
2	14.6
3	29.6
4	70.4
5	85.4
6	95.6



This is an example of a circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

Figure 34 - Traverse Points Located in Centroids for Circular Stack

Table 3 presents the location of traverse points in Circular Stacks as a percentage of stack diameter from **inside** wall on a traverse line.

Table 9 - Location of Traverse Points In Circular Stacks

(Percent of Stack Diameter from Inside Wall of Traverse Point)

Traverse Point number on a diameter	**Number of traverse points on a diameter**				
	4	6	8	10	12
4	93.3	70.4	32.3	22.6	17.7
5		85.4	67.7	34.2	25.0
6		95.6	80.6	65.8	35.6
7			89.5	77.4	64.4
8			96.8	85.4	75.0
9				91.8	82.3
10				97.4	88.2
11					93.3
12					97.9

For rectangular stacks, the centroids are much easier to determine, as shown in Figure 35. Table 10 presents the Cross Section layout for Rectangular Stacks.

Table 10 - Cross Section Layout for Rectangular Stacks

Number of Traverse Points	*Matrix Layout*
9	3 x 3
12	4 x 3

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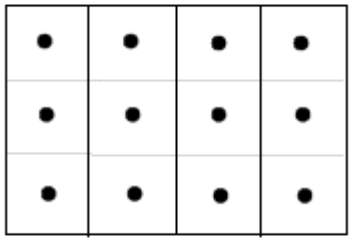
16	4 x 4
20	5 x 4
25	5 x 5
30	6 x 5
36	6 x 6
42	7 x 6
49	7 x 7



(This is an example of a rectangular stack cross section divided into 12 equal areas, with a traverse point at centriod of each area.)

Figure 35 - Traverse Points Located in Centroids for Rectangular Stack

Tips from an Old Stack Tester

After calculating the traverse point locations (before adding sample port nipple length), you can check your work quickly by noticing if the first and last traverse point distances added together equal the stack diameter; then if the second and next to last; then if the third and third from last; and so on.Measure the stack diameter from each sampling port – not all circular stacks are round! And not all rectangular stacks are perfectly rectangular.

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The procedure for locating each traverse point along the diameter for a circular stack and then marking the probe assembly or Pitot tube is as follows:

- On a Method 1 field data sheet (data sheet can be computer or calculator generated) multiply the stack diameter by the percentage taken from the appropriate column of Table 9.Table 10 - Cross Section Layout for Rectangular Stacks
- Add the port nipple length to each value for each traverse point.
- Convert the decimal fraction to 1/8th (0.125) of an inch for each point (English units only). For stacks = 60 cm (24 inches) in diameter, relocate any traverse points that are closer than 2.5 cm (1.00 inches) from the stack wall to 2.5 cm and label them as “adjusted” points. You may combine two successive points to form a single adjusted point, which must be sampled twice.
- For stacks, 60 cm (24 inches), do the same, except the adjusted distance is 1.3 cm (0.5 inch).
- Measure each traverse point location from the tip of the Pitot tube, and mark the distance with heat-resistant fiber tape or whiteout correction fluid, as illustrated in Figure 36 - Illustration of Marking Traverse Points on Probe Assembly.

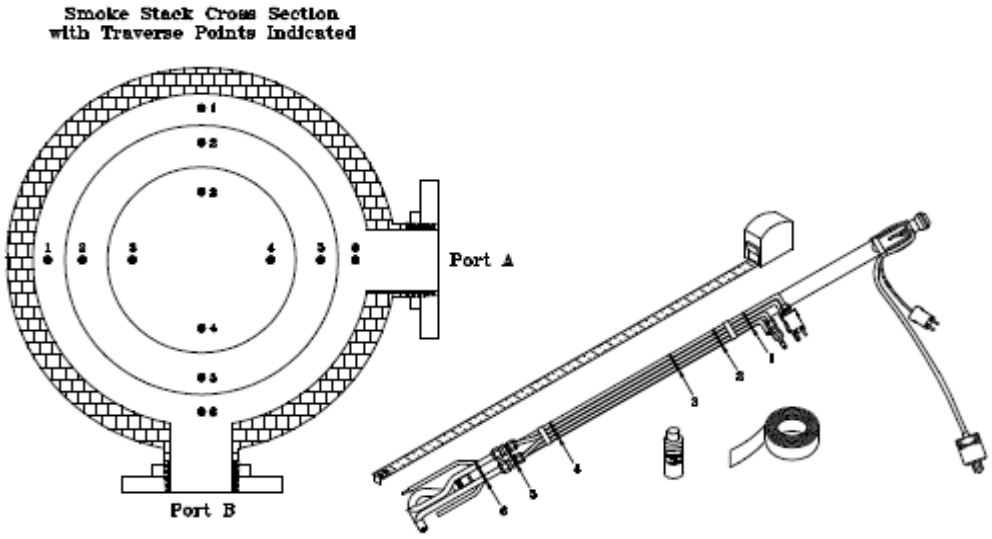

Figure 36 - Illustration of Marking Traverse Points on Probe Assembly

Tips from an Old Stack Tester

"White-Out" correction fluid used on paper has amazing properties for stack testing. It dries quickly and withstands stack heat and moisture very well. To remove from a

probe or Pitot tube, simply scrape it off with your pocketknife. Various tapes and black marking pens do not hold up against stack conditions nearly as well.

Method 1A Sample and Velocity Traverses for Small Stacks or Ducts

This procedure is the same as that in Method 1, except for the special provisions that apply to small stacks or ducts where 10.2 cm (4 in.) ≤ D ≤ 30.5 cm (12 in.), or for small rectangular ducts where 81.1 cm^2 (12.57 in.) ≤ A ≤ 729 cm^2 (113 $in.^2$). A standard type Pitot tube must be used for the velocity measurements and must NOT be attached to the sampling probe. In these small diameter stacks or ducts, the conventional Method 5 stack assembly (consisting of a Type S Pitot tube attached to a sampling probe equipped with a nozzle and thermocouple) blocks a significant portion of the duct's cross-section and causes inaccurate measurements. Therefore, for particulate matter sampling in small ducts, the gas velocity is measured either:

- Downstream of the sampling nozzle (for unsteady flow conditions), or
- In the same sample port alternately before and after sampling (for steady flow conditions).

The procedure for determining sampling location, traverse points, and flow rate (preliminary or other) in a small duct is as follows:

1. Select a site as shown in Figure 37.
2. Use Method 1 to locate traverse points for each site and choose the highest of the four numbers for traverse point number.
3. For PM (steady flow) or velocity (steady or unsteady flow) measurements, select one location and use the same criterion as Method 1.
4. For PM (steady flow) conduct velocity traverses before and after PM sampling to steady state conditions, i.e., withing ± 10% ($v_f/v_i \leq 1.10$).
5. For PM (unsteady flow), monitor velocity and sample PM at two separate locations.

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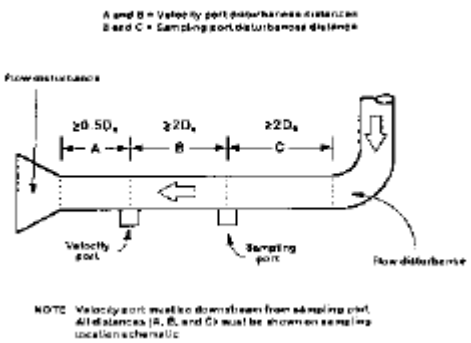

Figure 37 - Set-up of USEPA Method 1A Small Duct Sampling Locations

6. Complete Method 2 - Stack Gas Velocity and Volumetric Flow Rate

Method 2 is used to measure the average velocity and volumetric flow rate of the stack gas. There are two instances where Method 2 would be used:

- Prior to a particulate stack test series, to determine the size of the nozzle and length of the sampling run (preliminary velocity determination).
- During each stack test run, to ensure that the particulate sample is extracted from the stack at isokinetic conditions.

Background information and a description of USEPA Method 2 is provided immediately after the following section on configuring the XC-5000 user interface software and then using the XC-5000 to conduct stack gas velocity measurements.

The procedure for determining flow rate (preliminary or other) in a stack gas stream is as follows:

a) From the User Interface Main Menu, click the Method 2 button to access the Method 2 Menu that is shown in Figure 38, below.

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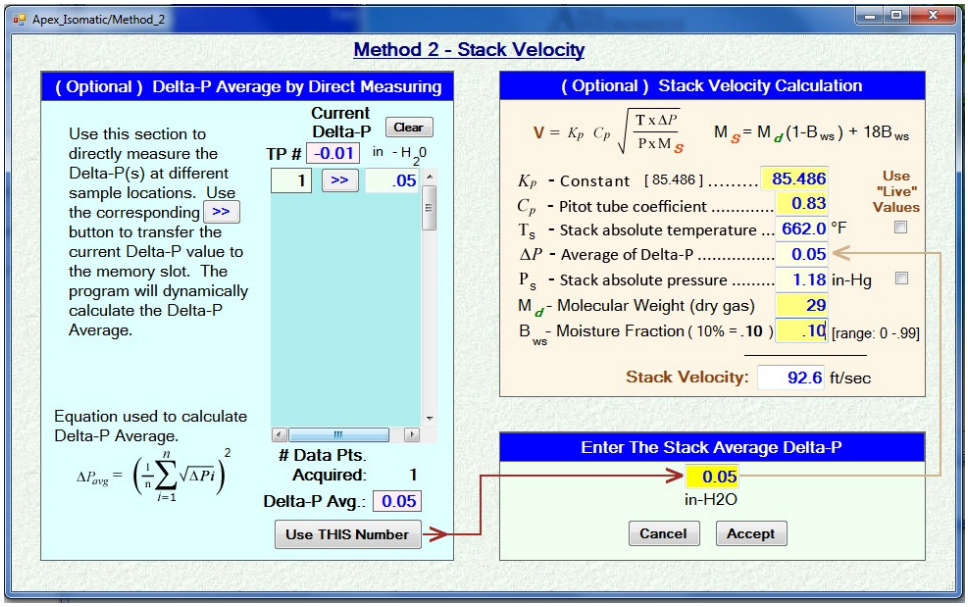

Figure 38 - Method 2 Menu Screen

b) If the average Δp for the sampling locations is known, you may enter that value directly into the field in the **Enter the Delta-P Average by Direct Measuring** Menu panel, then proceed to step 3. If the value is not known or if a new velocity traverse needs to be conducted, perform steps 3 - 11.

c) Enter the values for the following parameters in the (Optional) Stack Velocity Calculation Menu panel:

i) K_p – Constant: Use 85.49 for English Units, 34.97 if using Metric Units.

ii) C_p – Pitot tube Constant: Enter the actual Pitot tube coefficient supplied with its calibration documentation.

iii) T_s – Stack gas absolute temperature: Enter a value or if the actual "live" value is going to be measured during the velocity and particulate traverses, click this field's check box.

iv) P_s – Stack gas absolute pressure: If this value is known, it can be entered into the input field directly. Alternatively, the Stack Gas absolute pressure "live values" measured during the particulate traverse can be used in the automatic calculations of isokinetic sampling conditions by clicking the check box to the right of the input field.

v) Δp – Average Velocity Head: This value is imported automatically from the Delta-P Avg field in the **(Optional) Delta-P Average by Direct Measuring** Menu panel.

vi) M_d – Molecular Weight (dry gas): This value is supplied automatically from the completed "Other Pre-Test Information" menu. If the value being displayed is not acceptable, enter the new value in the input field.

vii) B_{ws} – Moisture Fraction: This value is also supplied automatically from the completed "Other Pre-Test Information" menu. If the value being displayed is not acceptable, enter the new value in the input field.

viii) When all data have been entered, click the Accept button at the bottom of the screen.

ix) Proceed to the following step 4 if a velocity traverse is going to be performed. If all data all data in this Method 2 menu is complete and a velocity traverse is not needed, proceed to the next section – **Nozzle Size Selection**.

d) Assemble the apparatus for flow velocity measurement:

i) Pitot tube with thermocouple, Pitot and thermocouple extension lines, inclined manometer, temperature display device, or

ii) Use Probe Assembly, Umbilical Cable and inclined manometer on Meter Console.

e) Mark the Pitot tube apparatus for traverse points according to Method 1.

f) Conduct a pre-test leak check of the Pitot and lines as follows:

i) Use a syringe and tygon tubing to gently pressurize the positive (impact) side of the Pitot tube opening until at least 7.6 cm (3 in.) H_2O registers on the manometer,

ii) Close off the impact opening and observe the pressure. It should remain stable for at least 15 seconds.

iii) Repeat for the negative (wake) Pitot.

g) Insert the Pitot tube into the stack to a marked traverse point, seal off the port opening with a rag or towel to prevent ambient effects. Observe the velocity head and temperature. When the readings are stable, press the >> button to store Δp data for that traverse point in the data table. Clicking this button will also add the next traverse point to the **(Optional) Delta-P Average by Direct Measuring** Menu Panel.

h) Move to each traverse point, reseal the port and observe the velocity head and temperature until it is stable, then press the >> to store each point's value in the **(Optional) Delta-P Average by Direct Measuring** Menu table.

i) Continue repeating steps 6 – 7 until all traverse points have been measured.

j) When all traverse points have been measured, click the Use THIS Number button to use the average Δp (showing in the field labeled "Delta-P Ave."). This value is then automatically transferred to the Enter the Stack Average Delta-P Menu panel field in the lower right hand portion of the window.

k) Conduct a post-test leak check (mandatory per the method, to prove that no leakage occurred) as described in step 6, above.

l) Proceed to the next section – **Nozzle Size Selection**

Discussion - Method 2 Description and Background Information

As mentioned previously, Method 2 is employed to obtain the average velocity and volumetric flow rate of the stack gas being sampled. This information is then used to determine the appropriate nozzle diameter and sample flow rates that will enable the extraction of the particulate matter sample at isokinetic sampling conditions. Also, this information is used to determine the length of the sampling periods.

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The equation for average gas velocity in a stack or duct is:

$$v_s = K_p C_p \left(\sqrt{\Delta p}\right)_{avg} \sqrt{\frac{T_{s(avg)}}{P_S M_s}}$$

Where vs =Average stack gas velocity, m/sec (ft/sec)

C_p = Pitot tube coefficient, dimensionless

Δ p = Velocity head of stack gas, mm H

T_s = Absolute average stack gas temperature, ° K (° R) P

P_s = Absolute stack gas pressure, mm Hg (in. Hg) = P

P_{bat} = Barometric pressure at measurement site, mm Hg (in. Hg) P

P_g = Stack static pressure, mm H

M_s = Molecular weight of stack on wet basis, g/g-mole (lb/lb-mole) = M

M_d = Molecular weight of stack on dry basis

Kp = Constant, 34.97 for metric system (85.49 for English system)

To obtain all values for input to the equation, values for molecular weight and moisture of the stack gas must be measured or estimated. Figure 1 illustrates the relationship of Methods 1,3 and 4 to Method 2.

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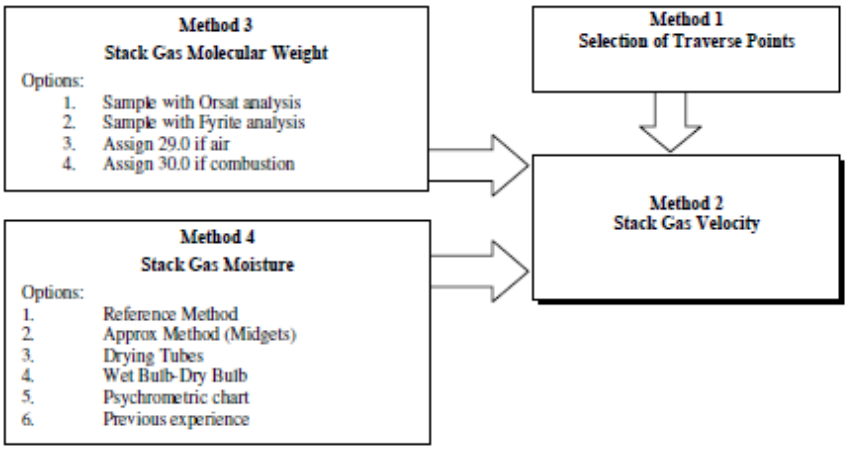

Figure 39- determination of Preliminary Velocity

Velocity measurements in a duct are made using a Pitot tube that is connected to an inclined manometer. Alternatively, a magnehelic pressure gauge or an electronic manometer can replace the inclined manometer, but each of these devices must be calibrated periodically against an oilfilled inclined manometer (see Section 4). The S-type Pitot tube is most often used in stack testing because:

- It is compact size makes it easy to attach to a Method 5 probe assembly, I
- It is relatively easy to manufacture,
- It is relatively insensitive to plugging in stack gas streams,
- It is relatively insensitive to yaw and pitch errors, and
- It has a fixed Pitot coefficient of 0.84 if manufactured and maintained to meet the geometric specifications of Method 2.

A standard or p-type (Prandl) Pitot tube with coefficient = 0.99 can also be used for these measurements. The S-type Pitot tube is inserted into the stack, so that one leg (hole opening) of the Pitot tube is pointing into the direction of gas flow, as shown in Figure 40. The leg pointing into the flow streamline measures impact pressure and the opposite leg pointing away from the flow measures wake of the gas stream. The velocity pressure Δ p is the difference between the impact and wake pressures:

$$\Delta p = P_i - P_w$$

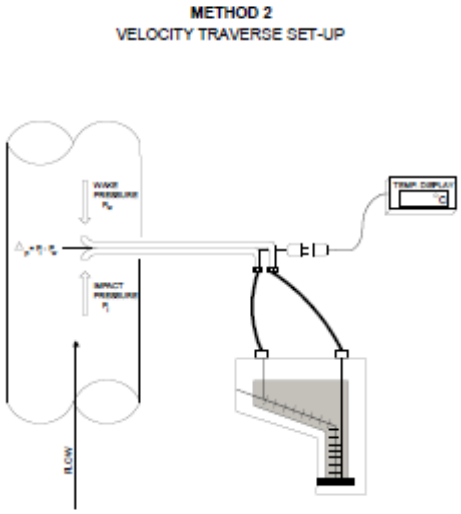

Figure 40 - Apparatus for Preliminary Velocity Measurement

Static Pressure

Static Pressure can be measured any of three ways:

- Using a static tap,
- Using a straight piece of tubing and disconnecting one leg of the manometer.
- Using the S-type Pitot tube and disconnecting one leg of the manometer, or
- The easiest way is to use a piece of metal tubing inserted into the approximate middle of the stack, connected to a U-tube water-filled manometer with the other end open to atmosphere. If the manometer deflects toward the stack, it is recorded as negative static pressure (less than barometric pressure). If the manometer deflects away from the stack, it is recorded as positive static pressure. If an inclined manometer is used, then the connection to the tubing must be placed on the negative (right-hand) side of the manometer to read a negative static pressure and switched to the positive (left-hand) side to read a positive static pressure. If a stack static tap is used, the procedure is identical.
- If an S-type Pitot is used to measure static pressure, the following procedure will work:

  1. Insert the S-type Pitot tube into the stack near the middle.
  2. Rotate the Pitot about 90° until zero (0) or null reading is obtained.

Holding the Pitot in place, read the pressure and record as the static pressure.

After the static pressure (Pg) is measured, the value must be converted from mm H_2O to mm Hg (inches H_2O to inches Hg) prior to use in the velocity equation (as P_s). The density of mercury is 13.6 times that of water, so the conversion equation is:

$$P_s = P_{bar} + \frac{P_g}{13.6}$$

Discussion - Barometric Pressure

With the XC-5000, the ambient barometric pressure at the measurement site is obtained automatically by using the internal barometric pressure sensor reading. This requires that the sensor be audited and calibrated as part of the test procedure and routine quality control requirements. An audit of this sensor can be made by contacting a local or nearby weather station (within 30 km) and obtaining the uncorrected station pressure.

(Note: Weather stations report barometric pressure corrected to sea level. Make sure to ask for the "uncorrected" pressure and their elevation above sea level.) You must also know the measurement site's elevation, and correct by subtracting 0.832 mm Hg for every 100 m rise in elevation (0.1 in. Hg for every 100 ft.). Calculate the sampling site barometric pressure, Pbar, as follows:

$$P_{bar} = P_r + 0.001(A - B)$$

Where, Pr = Barometric pressure at site ground level or at weather station, mm Hg (in.Hg)

A = Elevation at ground level or at weather station, m (ft. above sea level)

B = Elevation of the sampling site, m (ft. above sea level)

7. Method 5 – Determination of Particulate Emissions

a) Pre-Test Preparation (Before Traveling to Site)

i) Check filters visually against light for irregularities and flaws or pinhole leaks. Label the filters on the back side near the edge using numbering machine ink.

ii) Desiccate the filters at 20° ± 5.6° C and ambient pressure for = 24 hr, and then weigh at intervals of = 6 hr to a constant weight (= 0.5 mg change from previous weighing). Record results to ± 0.1 mg. During each weighing, do not expose the filter to the laboratory atmosphere for > 2 minutes and a relative humidity > 50%.

iii) ***Optional:*** If condensable or back-half particulate matter is to be measured, run analytical blanks of the deionized/distilled water to eliminate a high blank on actual test samples.

iv) Clean the Probe Liners and Probe Nozzles internally by brushing, first with tap water, then distilled/deionized water, followed by reagent-grade acetone. Rinse the Probe liner with acetone and allow to air-dry. Inspect visually for cleanliness and repeat the procedure if necessary. Cover the Probe Liner openings to avoid contamination. Nozzles should be kept in a case to avoid contamination or damage to the knife-edge. ***Note:*** Special cleaning procedures may be required for other test methods (for example, metals or dioxin).

v) Clean the Glassware (Filter Assemblies, Impingers and Connecting Glassware) internally by wiping grease from the joints, washing with glass cleaning detergent, rinsing with distilled/de-ionized water, followed by reagentgrade acetone, and then allow to air-dry. Cover all exposed openings with parafilm, plastic caps, serum caps, ground-glass stoppers or aluminum foil (not for metals!) to avoid contamination. ***Note:*** Special cleaning procedures may be required for other test method (for example, metals or dioxin).

b) Preparation of Sampling Train

i) Mark the Probe Assembly with heat-resistant tape or "White-Out" to denote the proper distance into the stack or duct for each sampling point.

ii) Insert the Probe Nozzle into the probe sheath union, and finger tighten the union fitting. Avoid over tightening to prevent cracking the glass probe liner. Keep the nozzle tip and the ball joint on the glass probe liner covered until the assembly of the train is complete and sampling is about to begin. Secure the Probe Assembly to the Sample Case by tightening the probe clamp.

iii) Prepare each set of impingers for a sampling run

iv) Impingers 1 & 2: 100 ml water in each

v) Impinger 3: Empty

vi) Impinger 4: 200 to 300 g of silica gel

Note: More than one sampling run can be prepared with multiple sets of glassware!

vii) Weigh each impinger to the nearest ± 0.5 g using a top-loading electronic balance (BAL-1200) and record initial weights on a field data sheet.

viii) Assemble the impingers in the Cold Box with U-tubes, Double "L" Adapter, and the Sample Case/Umbilical Adapter, using Ball Joint Clamps or Clips.

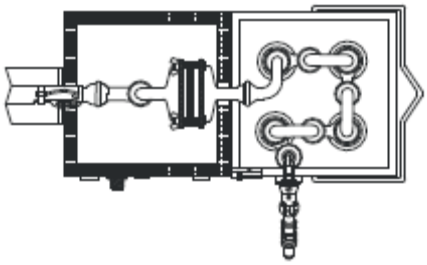

Figure 41 - Top View of Assembled Impingers

ix) Using tweezers or clean disposable surgical gloves, place the tared filter on the grooved side of the TFE filter support in the Filter Holder. Check the filter for tears after placement, and center on the filter support. Assemble the Filter Holder and tighten the

clamps around the Filter Holder to prevent leakage around the O-ring. Record filter number on the field data sheet.

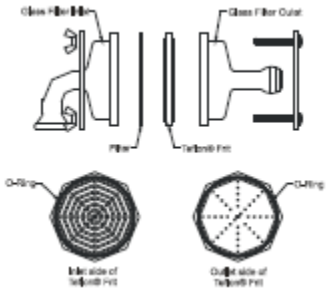

Figure 42 - Exploded View of Filter Assembly

x) Connect the Filter Holder and Cyclone Bypass (GN-1) in the Hot Box to the Probe Liner ball joint and to the "L" Adapter using Ball Joint Clamps. Close the Hot Box doors and fasten shut.

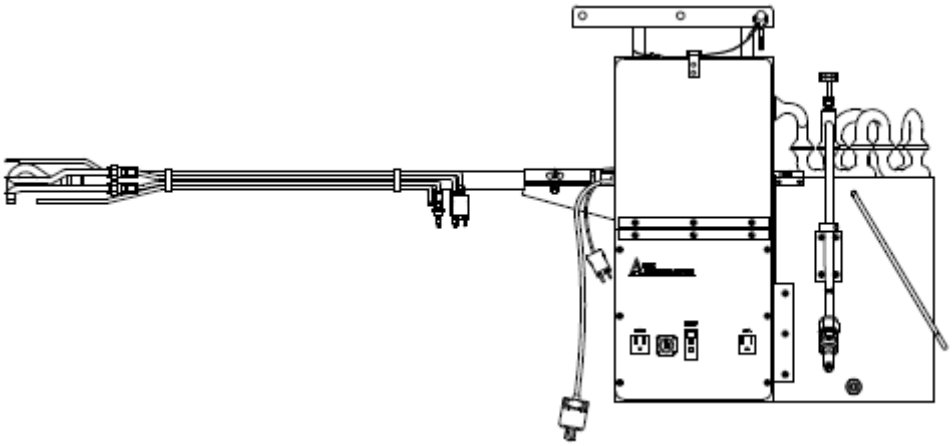

Figure 43 - Assembled Sampling Train Before Umbilical Hookup

xi) Connect the Umbilical Cable electrical and Pitot tube line connections to the assembled sampling train and to the Source Sampler Console. If used, connect the Orsat line also.

xii) Place the assembled sampling train near the first sample port, either on the monorail or other support.

xiii) Turn on and set probe and Hot Box heaters. Allow the Hot Box and probe to heat for at least 15 minutes before starting the test, and make periodic checks and adjustments to ensure the desired temperatures. Check all thermocouple connections by dialing through

each selection and noting ambient or heated temperatures. Place crushed ice and a little water around the impingers.

xiv) Optional: Leak-check the sampling train (see Leak-Check Procedure for Isokinetic Sampling Trains in Method 4 and Pitot Tube and Line Leak-Check in Method 2).

2) Preliminary Determinations Verification / Nozzle Size Selection

Method 5 provides several techniques for calculating the probe nozzle size and K-factor (ratio of Δ H/Δ p) needed for isokinetic sampling rate. The XC-5000 User Interface software automatically performs all of the required calculations.

Figure 44 shows the User Interface menu window where the information required for the system to calculate the nozzle size and K-factor is entered by the user.

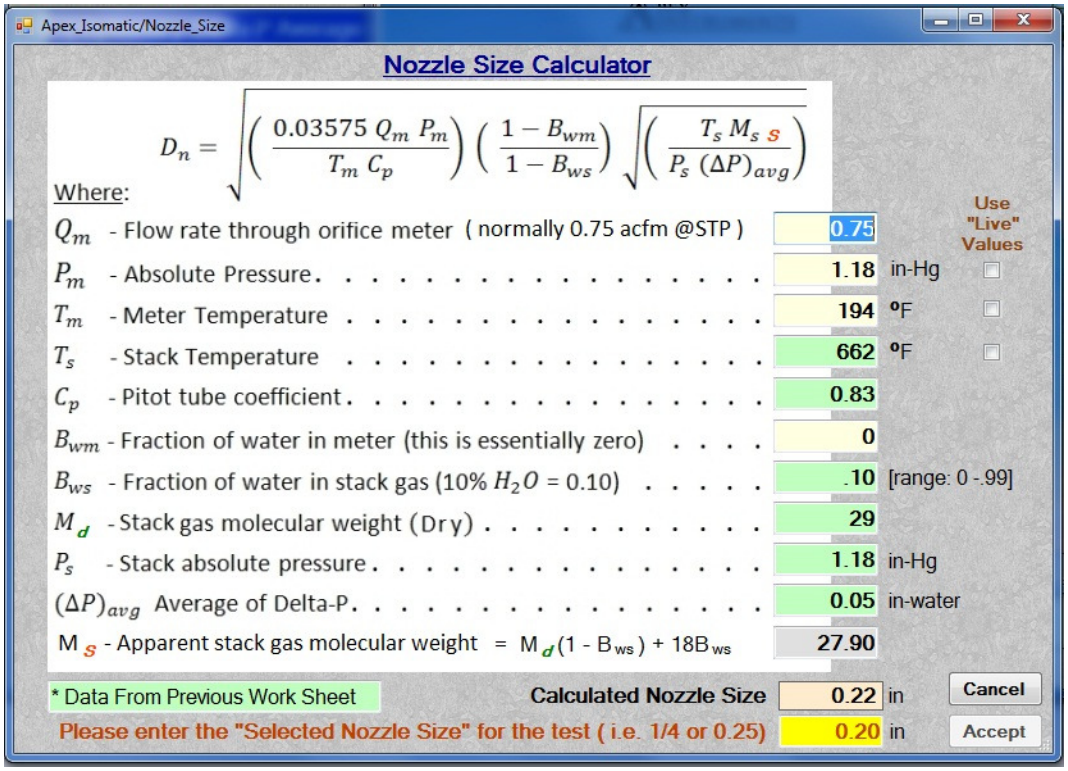

Figure 44- Nozzle Size Calculator Menu

All data in this menu is imported directly from the appropriate menus completed previously, except for the last field where the actual nozzle size (e.g., nozzle diameter) is entered.

The XC-5000 automatically calculates the **Desired** nozzle size and reports it in the field labeled "**Calculated Nozzle Size"** using the data for each parameter as displayed on this Menu screen.

Follow the steps below to complete the selection of the proper nozzle size.

a) Verify that all data completed in the Method 1 menu is correct.

b) Verify that all data completed in the Method 2 menu is correct.

c) Verify all data completed in the Other Pre-Test Data Menu is correct, e.g., Method 3 and Method 4 data.

d) Select a suitable Probe Assembly length such that all traverse points can be sampled.

e) Select a nozzle from your kit that is closest to the size given in the **Calculated Nozzle Size field** and enter the actual nozzle diameter in the field labeled "**Please enter the "Selected Nozzle Size" for the test (i.e., ¼ or 0.25)".** ***Note:*** *Do* ***NOT*** *change nozzle size during the sampling run.*

f) Click the radio buttons immediately to the right of the P_m, T_m, T_s fields to force the system to calculate isokinetic sampling parameters (e.g., sample flow) based on real time values measured during the particulate test.

g) Review all entries and selections. When satisfied, click the Accept button to store all data values in the progam.

3) K-Factor Calculation

The XC-5000 has two primary isokinetic operating modes:

- Operation based on automatically calculated, dynamic K-factor, or
- Operation based on the automatically calculate static K-factor.

When the Dynamic K factor mode is selected, the user can also choose to have the system calculate the isokinetic sampling rate based on real-time measurement of Stack Temperature, Meter Temperature and the absolute Meter Pressure.

Configuring the operating mode by setting the K-factor calculation method is managed using the K-Factor Calculator Menu, shown in Figure 45, below.

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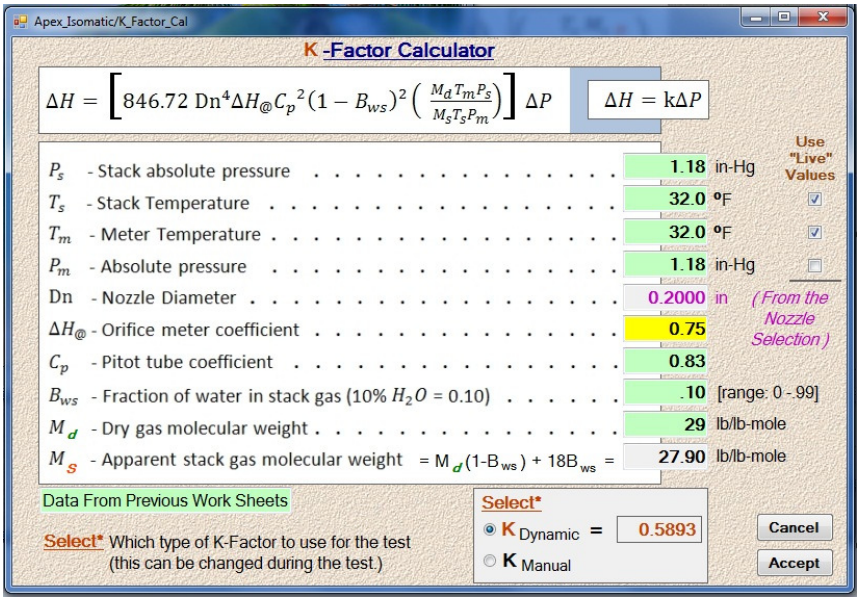

Figure 45 - K-Factor Calculator Menu Screen

Configuration of this menu is as follows:

a) From the Main menu, click K-Factor Calculation.

b) Verify accuracy of all fields with light green background. (Note: These values are imported directly from the associated fields in the previously completed menus. Generally, no value will be modified unless stack conditions have changed since a previous sample run.)

c) Verify the Nozzle Diameter field. If that value is not correct, enter the new value.

d) Enter the value for the orifice meter coefficient (ΔH@).

e) Click the appropriate check boxes for the desired parameters which will use the real-time "live" values for the calculation of the K-factor.

f) Click the appropriate radio button to choose either $K_{Dynamic}$ or K_{Manual}. Selecting $K_{Dynamic}$ will force the system to automatically control the isokinetic sampling rate based on a real-time calculation of the K-factor during the test. Selecting K_{Manual} allows the user to modify the sample flow rate during the test.

g) Review all parameter information and selections. When satisfied, click the Accept button to store the K-factor information in the XC-5000 program and return to the Main Menu.

h) Proceed to the next section, **Sample Run Procedure,** to continue performing a test.

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Background Information for Sizing the Probe Nozzle

Selecting the probe nozzle size and determining the K-factor requires collection of various preliminary information including:

- Average stack gas velocity head (Δ p). This is measured before the sample run, or from a previous test.
- Stack gas moisture fraction (B_{ws}) or percent ($\%H_2O$). This may be determined from a preliminary run, previous test, or calculated (see Method 4).
- Stack gas dry molecular weight (M_d). This may be determined from a preliminary run, previous test, or estimated (see Method 3).
- Stack gas pressure (P_s). This is measured before the sample run, or if the static pressure of the stack is very low (sample ports near stack exit) the barometric pressure is used.
- Source Sampler Console orifice calibration factor ($\Delta H_@$). This is determined from the laboratory calibration and should be readily available on-site (see Calibrations).
- Meter temperature (T_m). Temperature at the meter rises about 14° C (25° F) above ambient temperature due to heat from the vacuum pump. The ambient temperature should be measured at the Source Sampler Console site.
- Meter pressure (P_m). Same as barometric pressure.

The equation most commonly used for calculating the probe nozzle size is:

$$D = \sqrt{\frac{K_5 Q_m P_m}{T_m C_p (1 - B_{WS})}} \sqrt{\frac{T_s M_s}{P_s \Delta p_{avg}}}$$

Where, K_5 = 0.6071 (Metric units)

= 0.03575 (English units)

After selecting the appropriate nozzle from the Nozzle Set, shown in Figure 46, the K-factor (ratio of Δ H/Δ p such that Δ H = KΔ p) used to maintain isokinetic sampling rate at each traverse point is calculated for the sampling test run using the following equation:

$$K = \frac{\Delta H}{\Delta p} = \frac{K_6 D_n^4 \Delta H_@ C_p^2 (1 - B_{WS})(M_d T_m P_s)}{M_s T_s P_m}$$

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Where, D_n = Nozzle diameter, mm (inches)

T_m = Average DGM temperature, ° K (° R)

T_s = Average stack gas temperature, ° K (° R)

K_6 = 0.0000804 (Metric units)

= 849.842 (English units)

Figure 46 - 22 Probe Nozzle Set

8. Sampling Run Procedure

Conducting the particulate sampling run involves several key steps including:

- Completing the assembly and configuration of the sample train
- Completing a Pre-test Leak Check
- Installing the probe in the first sample port and locating the sample nozzle at the first sampling location
- Sample collection
- Completing a Post-test Leak Check
- Saving the completed test results to the data file.

Details for completing each of these steps is organized below following the software design flow.

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a) Completely assemble the sampling train and prepare the necessary associated equipment to perform a leak check, e.g., tubing/clamp to plug the sample nozzle, etc.

b) Perform a Pre-test Leak Check

i) From the Main Menu, click the Pre_Leak Test button to open the Leak Test Menu Screen. If a pop-up window is displayed, see Figure 47, below, indicating that the Test Data File has not yet been named, click the Yes button to name and save the file.

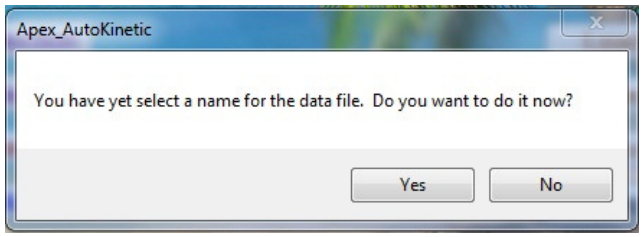

Figure 47 - Save Data File Pop-Up Window

ii) After the file is saved, the Leak Test Menu, shown in Figure 48, below, will open.

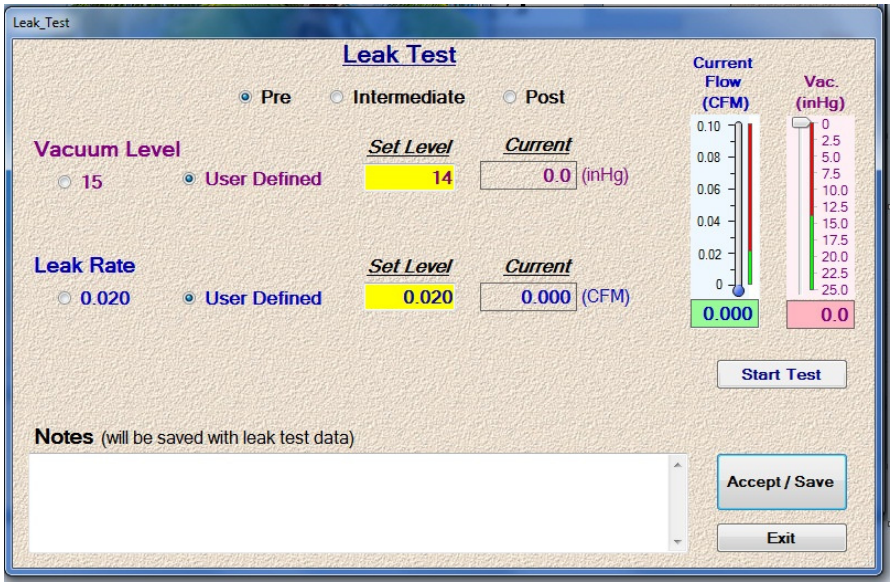

Figure 48 - Leak Test Menu Screen

iii) The user may choose to set the Vacuum Level and Leak Rates using the program defaults by clicking the radio button immediately to the left of the respective parameter values.

iv) To override the default values, click the radio button on the immediate left of the "User Defined" labels for the Vacuum Level and Leak Rate fields. If the "User Defined" radio buttons are selected, input the desired values into the fields directly below the "Set Level" labels.

v) Plug the nozzle, and when ready, click the Start Test button. The system will automatically start the pump and monitor the Vacuum Level and Leak Rate. After the Vacuum level reaches its set point, the system will close the "Leak check" solenoid valve in the Console and monitor the leak rate. If the leak rate is acceptable, the Menu screen will display "Passed".

vi) If desired, any notes or comments that you want to include in the data file and test report can be entered into the NOTES box.

vii) Click the Accept / Save button to save the results to the Test file and return to the Main Menu.

c) Perform a Sample Run

i) From the Main Menu, click on the Sample Data button to open the Monitor menu screen. This screen is shown in Figure 49 , below.

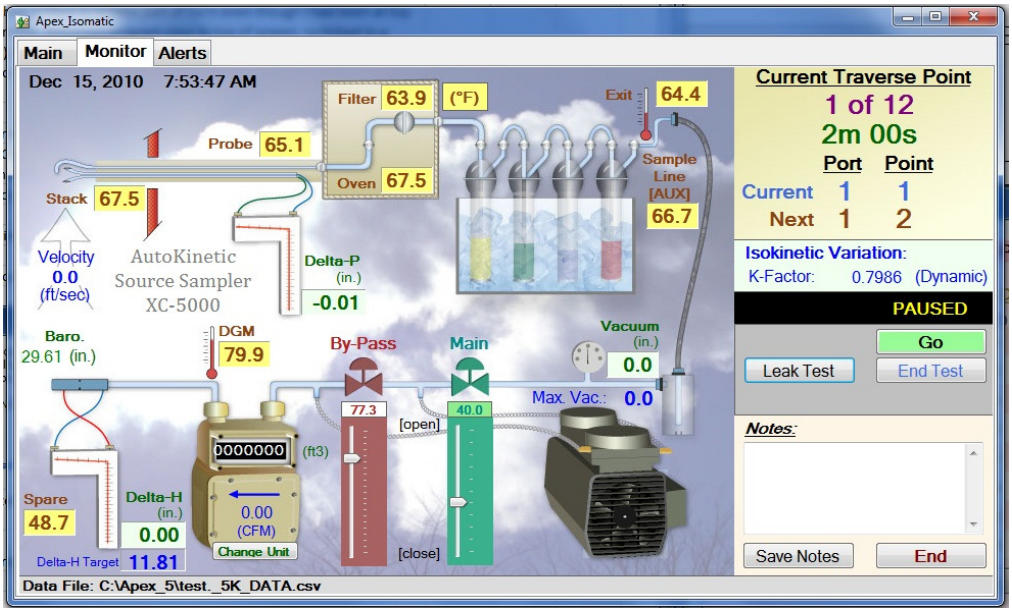

Figure 49 - Monitor Menu/Display Screen

ii) Open and clean the portholes of dust and debris

iii) Remove the nozzle cap, verify that the Hot Box/filter and probe heating systems are up to temperature, and check Pitot tube, temperature gauge, and probe alignments and clearances.

iv) Position the nozzle at the first traverse point. Immediately click Go to start the pump.

Note: If necessary to overcome high negative stack pressure, turn on the pump while positioning the nozzle at the first traverse point.

The Console will begin automatically controlling the sampling rate by adjusting the Main and By-Pass valves. The current traverse point and next traverse point will be displayed in the upper right hand side of the Monitor Menu/Display screen along with the sample time remaining for the current sampling point.

The time remaining display will begin flashing when the time approaches the end of the sample period (per the user selected warning alarm set point entered in the Method 1 Menu (see Figure 32).

As sampling progresses, the Console firmware will automatically record interim sampling data every minute to the data file.

Note: At any time during the test, notes can be added in the Notes box on the bottom right hand portion of the Monitor screen, If desired. Remember to click Save Notes before the test is ended to save any notes or comments that you want to include in the data file and test report.

v) When the probe is in position, block off the openings around the probe and porthole using duct tape, rags, gloves or towels (or flameproof materials for hot stacks).

Figure 50 - Blocking the Port During Sampling

vi) Traverse the stack cross-section for the same time period at each point without turning off the pump except when changing ports. *Do not bump the probe nozzle into the stack walls.*

vii) Periodically check all system parameters to ensure that the Console is operating properly and all parameters are maintained within specifications.

viii) Add more ice and, if necessary, salt to maintain a temperature <20° C (68° F) at the silica gel impinger exit.

ix) At the end of the sample run, click the End Test button in the Monitor Menu/Display screen, and remove the probe and nozzle from the stack. The instrument will

automatically finish record all sampling parameter data to the data file. The Monitor Menu will close and the software will return the user to the Main Menu.

d) ***Mandatory:*** Perform a Post Test Leak-Check of the sampling train at the maximum vacuum achieved during the sample run as follows:

i) Click the Post_Leak Test button on the Main Menu to open the Post-Leak Test Menu screen.

ii) After the file is saved, the Leak Test Menu, shown in Figure 48, below, will open.

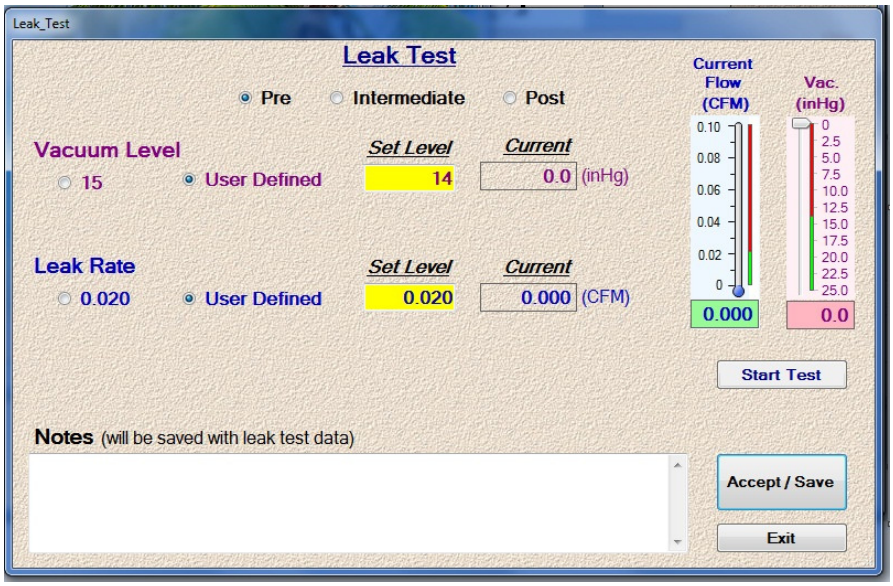

Figure 51 - Leak Test Menu Screen

iii) Verify that the correct radio button (located at the top, center of the menu screen) for the Post Leak Test is selected. If not, click the "Post" radio button.

iv) Set the Vacuum Level at the maximum level achieved during the test.

v) Verify the Leak Rate set point is correct. using the program defaults by clicking the radio button immediately to the left of the respective parameter values.

vi) Plug the nozzle, and when ready, click the Start Test button. The system will automatically start the pump and monitor the Vacuum Level and Leak Rate. After the Vacuum level reaches its set point, the system will close the "Leak check" solenoid valve in the Console and monitor the leak rate. If the leak rate is acceptable, the Menu screen will display "Passed".

vii) If desired, any notes or comments that you want to include in the data file and test report can be entered into the NOTES box.

viii) Click the Accept / Save button to save the results to the Test file and return to the Main Menu.

e) ***Mandatory:*** Leak-Check the Pitot lines. Record on the field data sheet. 13.

f) Allow the probe to cool. Wipe off all external particulate material near the tip of the probe nozzle, and cap the nozzle to prevent contamination or loss of sample. *Hint:* Open the Hot Box doors to allow the filter holder to cool.

g) Before moving the sampling train to the cleanup site, disconnect the probe from the Cyclone Bypass inlet and cover both ends. Do not lose any condensate that might be present. Disconnect the Filter Holder from the "L" Adapter and cap off the Filter Holder.

h) Disconnect the Umbilical Cable from the Sample Box and cover the last impinger outlet and first impinger inlet. Disconnect the Cold Box from the Hot Box. The Probe/nozzle Assembly, Filter Holder, and impinger case are ready for sample recovery

i) Transfer the probe and filter-impinger assembly to a cleanup area that is clean and protected from the wind.

9. Variations and Alternatives

a) Acceptable alternatives to glass probe liners are metal liners, for example, 316 stainless steel, Inconel or other corrosion resistant metals made of seamless tubing. These can be useful for cross-sections over 3 m (10 ft.) in diameter. Whenever practical, make every effort to use borosilicate glass or quartz probe liners. Metal liners will bias particulate matter results high.

b) For large stacks, consider sampling from opposite sides of the stack to reduce the length of probe.Use either borosilicate or quartz glass probe liners for stack temperatures up to 480° to 900° C (900 – 1,650° F). The softening temperature for borosilicate glass is 820° C (1,508° F), and for quartz it is 1,500° C (2,732° F).

c) Rather than labeling filters, label the shipping containers (glass or plastic Petri dishes), and keep the filters in these containers at all times except during sampling and weighing.

d) Use more silica gel in impinger 4, if necessary, but ensure that there is no entrainment or loss during sampling. Hint: Loosely place cotton balls or glass wool in the neck of the silica gel impinger outlet stem.

e) If a different type of condenser (other than impingers) is used, measure the amount of moisture condensed either volumetrically or gravimetrically.

f) For moisture content, measure the impinger contents volumetrically before and after a sampling run. Use a pre-weighed amount of silica gel in a shipping container, then empty the silica gel after the run back into the container for weighing at another time.

Figure 52 - Recovering Silica Gel for Weighing

Figure 53 – Determining Moisture Volumetrically

g) If the total particulate catch is expected to exceed 100 mg or more or when water droplets are present in the stack gas use a Glass Cyclone between the probe and Filter Holder. If high pressure drops across the filter (high vacuum on the gauge) causing difficulty in maintaining isokinetic sampling, replace the filter. Suggestion: Use another filter assembly rather than changing the filter itself. Before installing a new filter, conduct a leak-check. Add the filter assembly catches for the total particulate matter weight. Use a single train for the entire sampling run, except when simultaneous sampling is required in two or more separate ducts or at two or more different locations within the same duct, or in cases where equipment

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failure necessitates a change in trains. In all other situations, obtain approval from the regulatory agency before using two or more trains.

h) When two or more trains are used, analyze separately the front-half and (if applicable) impinger catches from each train unless identical nozzle sizes were used on all trains. In this case, the front-half catches may be combined (as may the impinger catches) and one analysis of front-half catch and one analysis of impinger catch may be performed. Consult with the regulatory agency for details concerning the calculation of results when two or more trains are used.

i) If a flexible line is used between the first impinger or condenser and the Filter Holder, disconnect the line at the Filter Holder, and let any condensed water or liquid drain into the impingers or condenser.

j) Do not cap off the probe tip too tightly while the sampling train is cooling down, as this would create a vacuum in the Filter Holder, which may draw water from the impingers into the Filter Holder.

10. Sample Recovery

Sample Recovery is extremely important because that is where sample loss can occur (bias results low due to sampler errors or blunders) or contamination can be introduced (bias results high).

a) Place 200 ml of acetone from the wash bottle being used for cleanup in a glass sample container labeled “Acetone Blank”.

b) Inspect the train prior to and during disassembly, and note any abnormal conditions on the data sheet.

c) Container No. 1 – Filter

   i) Using a pair of tweezers (TW-1) and/or clean disposable surgical gloves, carefully remove filter from the Filter Holder, and place it in its identified petri dish container. If necessary, old the filter such that the particulate matter cake is inside the fold.

   ii) Using a nylon bristle brush (DB-3) and/or a sharp-edged blade (LS-1), carefully transfer to the petri dish any PM and/or remaining pieces of filter or filter fibers that adhere to the filter support or gasket.

d) Container No. 2 – Acetone Rinses – Recover any particulate matter from the internal surfaces of the Probe Nozzle, swaged union fitting, probe liner (use a glass funnel to aid in transferring liquid washed to the container), front half of the Filter Holder, and (if applicable) the cyclone, and recover all rinses in a single glass container as follows:

   i) Before cleaning the front half of the Filter Holder, wipe clean all joints of silicone grease.

   ii) Rinse with acetone, brush with small nylon bristle brush, and rinse with acetone until there are no visible particles. Make a final acetone rinse.

   iii) For probe liner, repeat rinse, brush, rinse sequence at least three times for glass liners, and six times for metal liners.

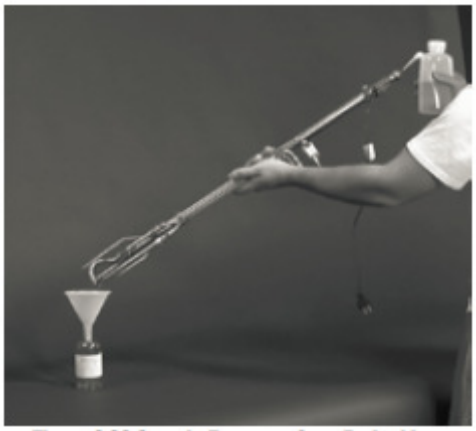

Figure 54 - Sample Recovery from Probe Lines

Tips from an Old Stack Tester

Instead of trying to catch the probe rinse with a glass funnel and sample container (likely step for sample loss), clamp an Erlenmeyer flask outfitted with female ball joint on the probe liner ball joint and conduct the probe rinse procedure. If the probe is short, one person can perform the brushing and rinsing.

Figure 55 - Rinsing Probe Nozzle

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Figure 56 - Brushing Probe Nozzle

Figure 57 - Front Half Acetone Rinse Samples

iv) Make a final rinse of the probe brush with acetone.

v) For Probe Nozzle, use the nylon nozzle brush and follow the same sequence of rinse, brush, rinse as for the probe linger.

vi) After completing the rinse, tighten the lid on the sample container. Mark the height of the fluid level. Label the container.

e) Container No. 3 – Silica Gel

i) Determine whether silica gel has been completely spent, and note on data sheet its condition and color.

ii) Either reuse in the next run, using the final weight as the initial weight for the new sampling run, or discard and reload impinger.

f) Impinger Water

i) Note on the data sheet any color or film in the liquid catch.

ii) Discard the liquid, unless analysis of the impinger catch is required. Store as is appropriate.

g) Whenever possible, ship sample containers in an upright position.

At the conclusion of each sampling run, it is prudent to calculate the stack gas moisture (for the next sampling run) as well as the average isokinetic rate. To calculate the stack gas moisture content (B_{ws}), the following equations are used to compute the sample gas volume (V_{mstd}) and gas moisture volume ($V_{wc(std)}$):

$$V_{m(std)} = K_3 Y \frac{V_m \left(P_{bar} = \frac{\Delta H}{13.6}\right)}{T_m}$$

Where, Δ H = Average orifice tube pressure during sampling, mm H2O (in. H2O)

V = Dry gas volume measured by dry gas meter, dcm (dcf)

Tm = Absolute temperature at dry gas meter, ° K (° R)

Y =Dry gas meter calibration factor

K_3 = 0.3858 ° dK/mm Hg (metric units)

= 17.64 ° R/in. Hg (English units)

$$V_{m(std)} = K_2 (W_f - W_i)$$

Where, W_f = Final weight of water collected, g

W_i = Initial weight of water collected, g

K_2 = 0.001335 m3/g (Metric units)

= 0.04715 ft3/g (English units)

$$B_{WS} = \frac{V_{wc(std)}}{V_{m(std)} + V_{wc(std)}}$$

Where, B_{WS} = Proportion of water vapor, by volume, in the gas stream.

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Next, the average stack gas velocity is calculated. The equation for average gas velocity in a stack or duct is:

$$V_s = K_p C_p \left(\sqrt{\Delta p}\right)_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$

Where V_s =Average stack gas velocity, m/sec (ft/sec)

C_p = Pitot tube coefficient, dimensionless

Δp = Velocity head of stack gas, mm H

T_s = Absolute average stack gas temperature, ° K (° R) P

P_s = Absolute stack gas pressure, mm Hg (in. Hg) = P

P_{bat} = Barometric pressure at measurement site, mm Hg (in. Hg) P

P_g = Stack static pressure, mm H

M_s = Molecular weight of stack on wet basis, g/g-mole (lb/lb-mole) = M

M_d = Molecular weight of stack on dry basis

K_p = Constant, 34.97 for Metric system (85.49 for English system)

The average percent isokinetic sampling rate is calculated as:

$$\%I = \frac{K_4 T_s V_{m(std)}}{P_s V_s A_n \theta (1 - Bws)}$$

Where, A_n = Cross-sectional area of the nozzle, m_2 (ft_2)

θ = Sampling time, minutes

K_4 = 4.320 (Metric system)

= 0.09450 (English system)

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Tips From an Old Stack Tester

During port changes, many stack testers scan or quickly average values for vΔ *p,* ΔH*, stack gas temperature and DGM temperature to calculate %I before the sampling run is finished (this all assumes that B*

will not change substantially). Some sophisticated calculator programs and most laptop computer programs monitor %I for each point and cumulatively.

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Recommended Reading List for Isokinetic Sampling

Code of Federal Regulations. Title 40. Part 60, Appendix A. Office of the Federal Register. National Archives and Records.

Compliance Test Coordination and Evaluation. Workshop Manual. U.S. Environmental Protection Agency. APTI 01-94a. 1994.

Jahnke, J. A., et al. *Source Sampling for Particulate Pollutants.* Student Manual, APTI Course 450. Edition 3.0. Raleigh, NC: North Carolina State University, 1995.

Manual for Coordination of VOC Emissions Testing Using EPA Methods 18, 21, 25, and 25A. U.S. Environmental Protection Agency. EPA 340/1-91-008. September 1991.

Quality Assurance Handbook for Air Pollution Measurement Systems. Vol. 3. Stationary Source Specific Methods, Section 3.4. U.S. Environmental Protection Agency. EPA-600/4-77-027b. 1988. Rom, J. J.

Maintenance, Calibration, and Operation of Isokinetic Source Sampling Equipment. Publication No. APTD-0576. Office of Air Programs. U.S. Environmental Protection Agency. Research Triangle Park, NC 1972

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System Audits, Calibration and Maintenance

Setting up and adhering to a routine maintenance program will help to ensure trouble-free operation of the isokinetic sampling system. In addition, a carefully documented maintenance and calibration system will help to assure that accurate results are obtained during stack testing activities. The following text describes maintenance and troubleshooting procedures for the various subsystems of the isokinetic sampling system.

Test results from a stack emission test are meaningless without calibration and audits of the equipment components. The creation and maintenance of a regularly scheduled calibration and record keeping program are critical to conducting any stack testing program. Without calibration, sampling cannot be verified as having been conducted isokinetically.

The results of a particulate sampling test cannot be checked for accuracy because no independent technique or test atmosphere exists to provide a standard or known particle concentration. Collaborative testing conducted by the USEPA has determined that the interlaboratory standard deviation is ± 12.1%. Only through careful calibration, maintenance, and record keeping can the stack tester ensure that the data collected during the stack test program are representative of particle concentrations and mass emission rate.

Components of the particulate sampling system which require calibration are:

1. Dry Gas Meter and Orifice Tube

2. Thermocouples (stack, probe, filter box, impinger exit, and dry gas meter) and Digital Temperature Indicator

3. Pitot Tube

4. Sampling Nozzles

5. Probe and Filter Box Heater System.

The following table presents a matrix showing the component calibration requirements for a particulate sampling system.

Table 11 - System Components Calibration Requirements

Component	Calibrated Against	Acceptance Limits	Frequency	Action If Unacceptable
Dry Gas Meter Initial 5-point	1. Wet Test Meter 2. Secondary Reference DGM	Y i = Y ± 0.05Y	Semiannually	Recalibrate, repair or replace

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Post-test 3-point	Wet Test Meter 2. Reference DGM 3. Critical Orifices			Recalibrate at 5 points
Orifice Tube	Measured during DGM calibration			Repair or replace
Thermocouples and Digital Indicator	Certified Hg-in-glass thermometer in ice slush and boiling water			Recalibrate, repair or replace
Pitot Tube	1. Standard Pitotin wind tunnel andcalculate Cp	If part of Probe Assembly, calibrate with assembly. s □ 0.001 for side Aand side B	If part of Probe Assembly, calibrate with assembly. s □ 0.001 for side Aand side B	Recalibrate, repair or replace
	2. Measure with angle indicator to demonstrate meeting geometry specifications and assign C p = 0.84	± 10° a a 1 ± 10° ß 2 ± 5° ß 1 ± 5° Z = □ 0.125” 2 W = □ 0.031” P □ 0.063” 0.188”□ D - P	Quarterly, or after each field test	Recalibrate, repair or replace

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		A B □0.375”		
Sampling Nozzles	Micrometer with at least 0.025-mm (0.001inch) scale	Average of three inner diameter measurements; Δ D ± 0.1-mm (0.004-inch)	Before each field use	Recalibrate, reshape, or resharpen when dented or corroded
Probe and Filter Box Heater System	Gas thermocouple	Capable of maintaining 120°C ± 14°C at 20-lpm flow rate	Initially	Repair or replace, and verify calibration

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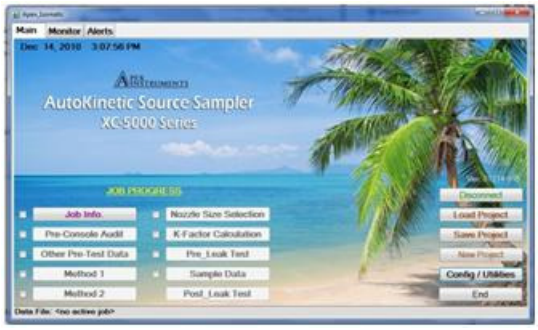
CALIBRATION PROCEDURES



1. Open Main Screen, Click on <Connect > button.

   If connection is established, <Connect> button label will change to “Disconnect”.

   Also, date and time will be displayed in upper right-hand corner

2. When connection is made, click on <Config/Utilities> button.

3. To perform a System Calibration: click on <Calibrations> button.

   Other items on this screen:

   a. <Set clock> – XC-5000 date / time will be set to the date and time on computer connected to XC-5000.
   b. <Console Audit> – See Console Audit Procedure
   c. <Reset XC-5000> – Returns all XC-5000

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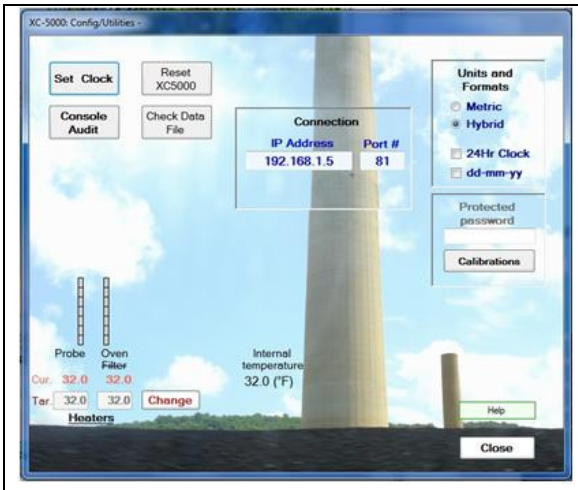
<table>
<tr>
<td> 
</td>
<td>parameters to their default states
d. <Check Data File> –Opens file manager to access an XC-5000 data file.
e. Connection Box – IP Address and Port “ for identification of XC-5000 by laptop
f. Units and Formats Box –Select desired measurement units and date/time format
g. Heaters –Use to set heaters to allow system to warm up during software/hardware configuration process</td>
</tr>
</table>

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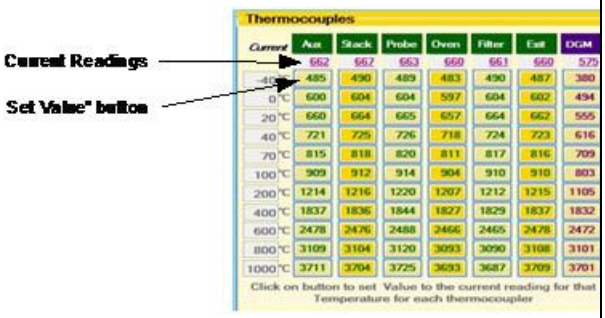
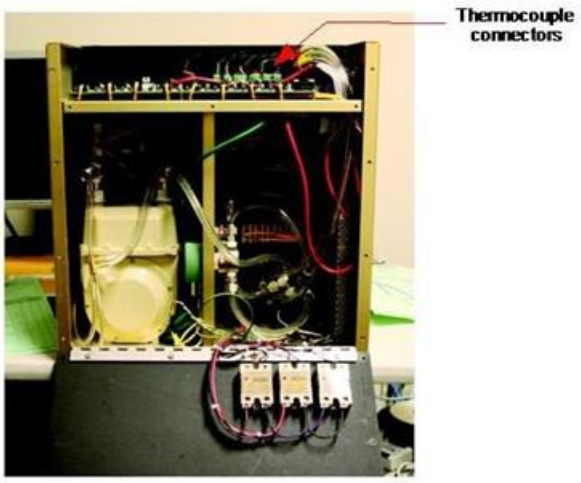
4. Enter the password “enable” in the “Protected Password” field in the upper right hand portion of the screen to allow values to be entered and accepted.

- Calibration of each system component can be performed in any order desired.
- For each sensor calibration parameter, the current value is shown in **purple font.**
- When all desired sensor calibrations are completed, press the Save button at the bottom right hand side of this screen.



5. Thermocouple Calibration
   i. Insert thermocouple calibration input into Aux connector on front panel of the instrument.
   ii. Set the calibration device to the desired temperature (normally start at -40° C). When the “Current” reading (located in the directly under “Aux” label) is stable, click the button for that parameter and temperature.
   iii. Move thermocouple calibration input to the Stack connector, and repeat as for the Aux thermocouple.
   iv. Complete the calibration of all thermocouples at a given temperature, then begin the calibration at the next temperature following the same steps as described in a-c.

Note: To calibrate the DGM temperature sensor, the instrument must be removed from its case, then the back panel must be opened to expose the thermocouple A/D input connectors located on the right hand side of main board when viewing the box from back to front. The DGM thermocouple

	connector is second from the right. Remove the wires and insert the thermocouple simulator leads. It may be easiest to calibrate the DGM thermocouple A/D for all temperatures before continuing with the calibration of the other sensor.

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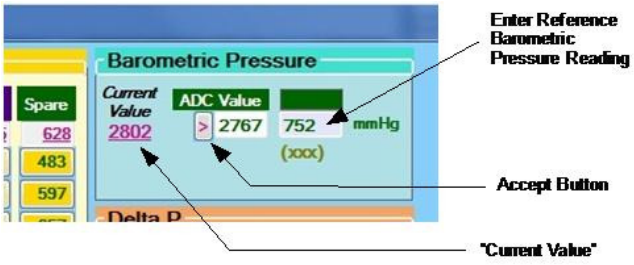
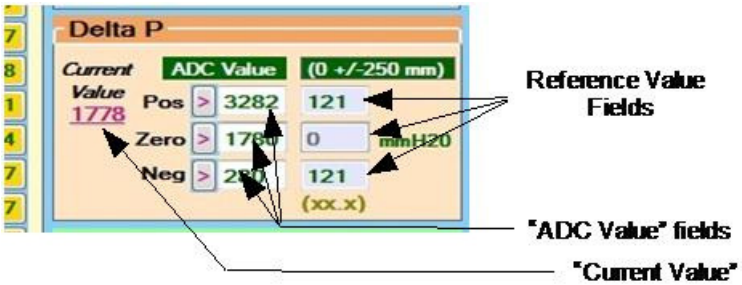
<table>
<tr>
<td> 
</td>
<td>6. Barometric Pressure Sensor Calibration
i. Obtain reference barometric pressure for local conditions.
ii. Enter reference barometric pressure into Reference field.
iii. Click <Accept> button ( ) to accept the current ADC value. (If the value is accepted, the reading in the “ADC Value” field will agree with the “Current Value”.</td>
</tr>
<tr>
<td> 
</td>
<td>7. Delta P Pressure Sensor Calibration
i. Configure a syringe, tubing and Pressure Reference Device and connect the equipment to the +Delta P quick connect port fitting on the instrument front panel.
ii. Apply a positive pressure using the syringe until the “Current Value” is between 3800 – 4000.
iii. When the “Pos” ADC value stabilizes, enter the reference meter value in the “Pos” reference value field. This is the field in the column directly under the label “(0 +/-250 mm).
iv. Next, click the <Accept> button ( ) to accept the Current ADC value.
v. Remove the syringe/tubing/ reference manometer apparatus.</td>
</tr>
</table>

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	vi. When the “Zero” ADC value stabilizes, enter the reference meter value in the “Zero” reference value field. vii. Click the <Accept> button ( ) to accept the current ADC value. viii. Attach the syringe/tubing/reference manometer apparatus to the –DeltaP port. ix. Apply **positive** pressure using the syringe until the “Current Value” is between 3800 – 4000. x. When the “Neg” ADC value stabilizes, enter the reference meter value in the “Neg” reference value field. xi. Click the <Accept> button ( ) to accept the current ADC value. Note: Due to the way the Delta P pressure sensor functions, a *positive* pressure is input on both the +Delta P and – Delta P ports when performing the calibration.

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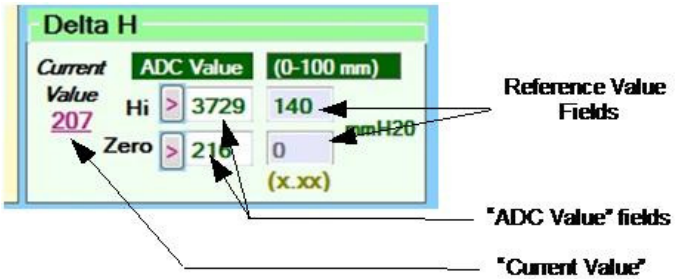
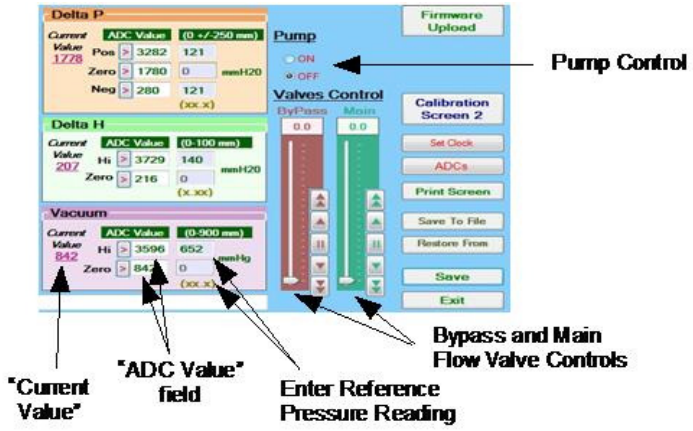
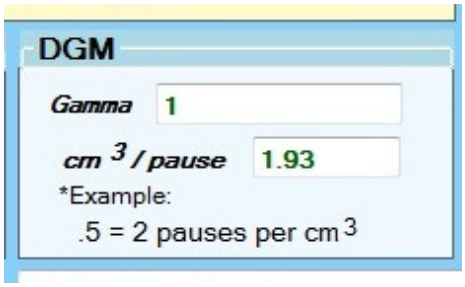


8. Delta H Pressure Sensor Calibration
   i. Configure a syringe, tubing and Pressure Reference Device and connect the equipment to the +Delta H quick connect port fitting on the instrument front panel.
   ii. Apply **positive** pressure using the syringe until the "Current Value" is between 3800 – 4000.
   iii. When the current value is in the desired range and stable, click the <Accept> (>) button to accept the current ADC value.
   iv. Remove the syringe/tubing/Pressure Reference Device and allow the Delta H current value to stabilize, then press the > button to accept the ADC value.



9. Vacuum Sensor Calibration
   i. Connect the pump line to the "Pump" quick connect fittings on the front panel of the Console.
   ii. Configure a Pressure Reference Sensor with a closed fitting and connect it into the "Sample" port fitting on the Console front panel.
   iii. Turn the pump on via the Pump Control radio button and adjust the Main Flow Valve control slider to obtain sufficient sample vacuum.
   iv. When the Vacuum "Current Value" is stable, input the Reference Sensor reading in the field immediately below the "(0-500 mm Hg)" label, the click the > button to accept the reading.
   v. Turn the pump off, release the pressure and wait for the "Current Value" to stabilize. It should be near zero. When the

	"Current Value" is stable, click the button to accept the reading.
	Note: The value in the Gamma box is provided by Apex or other calibration laboratory when the console is manufactured or a replacement meter is supplied. Generally, the calibration of the dry gas meter (DGM) meter is performed by comparison of the instrument DGM to a wet test meter other reference volume measurement system. The ccm/pause (should be pulse) is a factor set by the factory that correlates the volume measured per revolution of the meter shaft to the meter's digital encoder. As older instruments were supplied with a meter that rotated at slower speed than the current meter. To account for older models plus potential differences in the future, this field allows the optical encoder to be calibrated to the meter shaft rotational speed. This field is not a variable. The factor for current meters is always 1.93; older meters will have a factor of 0.5. Please consult Apex support if you have any questions about the correct setting for your system.

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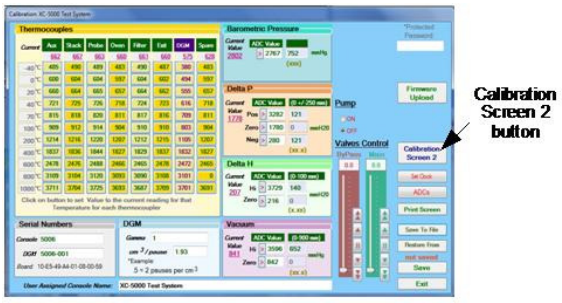
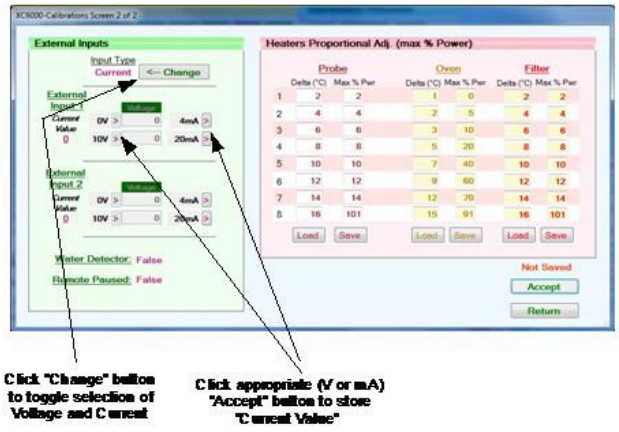
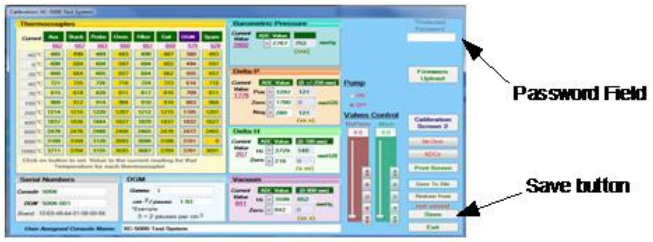




10. Calibration of External Analog Inputs
    i. Click the Calibration Screen 2 button located in the mid, right hand side of the Calibration Screen.
    ii. Connect the reference signal generator into the appropriate external input connector and generate a signal representing a zero (0) unit input.
    iii. When the "Current Value" is stable, click the appropriate [>] button to accept that value.
    iv. Generate a signal representing a full scale input from the external input, then click the appropriate [>] button to accept that value.
    v. When all external inputs have been calibrated, click the [Accept] button to store the new calibration information in the calibration table.
    vi. Click the [Return] button to return to the first Calibration page.



11. When all desired sensor calibrations are completed, press the [Save] button at the bottom right hand side of this screen. This will store all sensor calibrations to the system's calibration data table.

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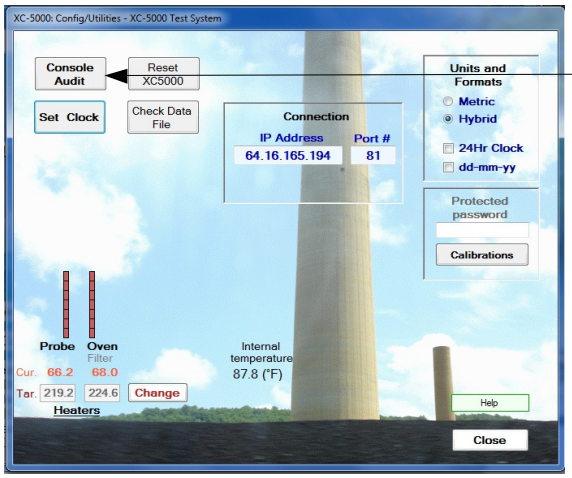
AUDIT PROCEDURES

1. To access the Audit Menu from the Main Menu screen, connect to the instrument, then click the Config/Utilities button.



2. Click the Console Audit button on the Config/Utilities Menu screen.

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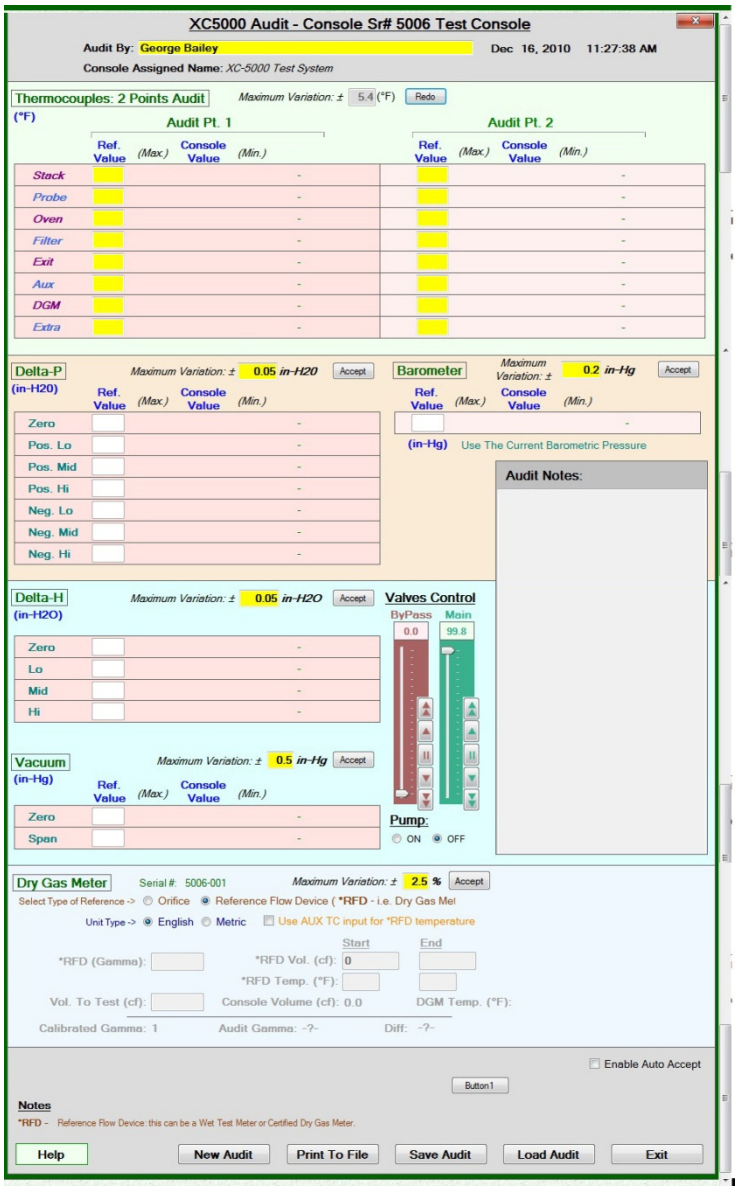
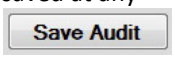


General Notes on interfacing with the Audit Menu window:

- The scroll bar on the right hand side of the menu window can be used at any time to reposition the field of view.
- Any field highlighted in yellow is an input field.
- To perform an audit of any sensor and turn on the input fields, the user must first click on the Accept button. In the menu screen shot on the left side of this page, the Accept button had already been clicked. This resulted in activating the "Ref. Value" input fields for the Thermocouples audit, and it changed the condition of the Accept button to Redo .
- **IMPORTANT:** Confirm the maximum variation allowable for each sensor before clicking the Accept button when starting an audit. The acceptable maximum variation is source dependent in some cases. For instance, per EPA Method 2, the temperature sensor must be calibrated at at temperature within +/- 10 % of the absolute stack pressure. The calibration tolerance is then ≤ 1.5 % of the reference temperature sensor.
- To erase any existing audit results for a given sensor audit, the Redo button for that sensor can be clicked.
- At the bottom of the menu, there is a check box labeled "Enable Auto Accept". When this box is checked, the program automatically verifies the pass/fail result as soon as the

	reference value is entered for a given audit point. No further user input is required for the program to recognize the result of the audit point. • An audit file can be saved at any time by clicking the  button at the bottom of the menu. • To erase all audit data and begin a new audit, click the button at the bottom of the menu window. (Use scroll bar on right hand window border to reposition menu on your computer display.) • User must save the audit before exiting this menu or all audit data will be lost. A warning message is displayed when the Exit button is clicked to help ensure results are inadvertently lost.

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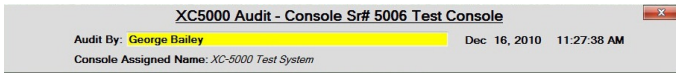
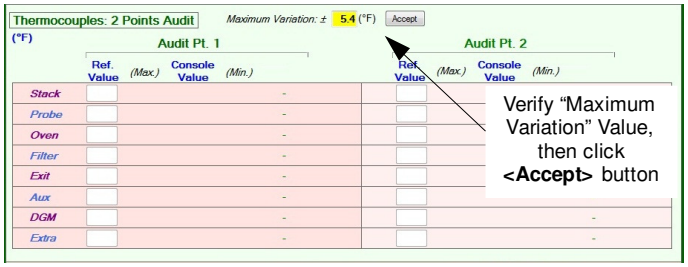
System Audit Procedure



1) Scroll to the bottom of the Audit menu using the scroll bars on the right margin of the window.
   a) Click **New Audit** to start a new Console Audit.
   b) Click **Load Audit** to continue an existing audit.
2) Automatic acceptance of audit results: If you wish to have the program automatically calculate and accept the result of any parameter's audit point, scroll to the bottom of the menu and click the check box labeled "Enable Auto Accept".
3) Click on the "Audit By:" field and enter the auditor's name / identification.



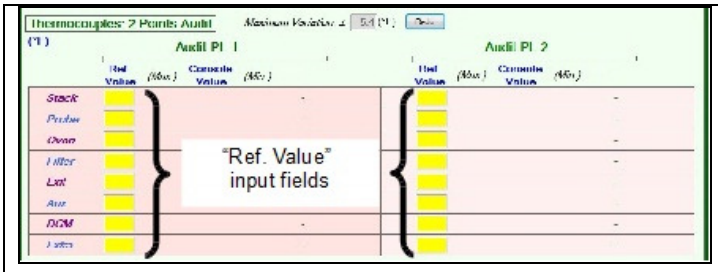
4) Thermocouple Audits
   a) Verify or edit the Maximum Variation value, then click **Accept** to activate the reference value fields.

      Note: The Reference Value ("Ref Value") field color will change from white to yellow background to signal acceptance of the Maximum Variation value.

   b) Audit Point 1:

      i) Prepare an ice water bath in an insulated container. Insert the thermocouple(s) being audited into the ice bath with a mercury-in-glass thermometer or other temperature reference device.

      ii) When the reference device reading



is stable, enter the temperature in the "Ref Value" field for each thermocouple being audited. After each reference value is enter, the "Console Value" will then be displayed along with the message Pass or Fail and the difference between the stack thermocouple and the reference device measurements.

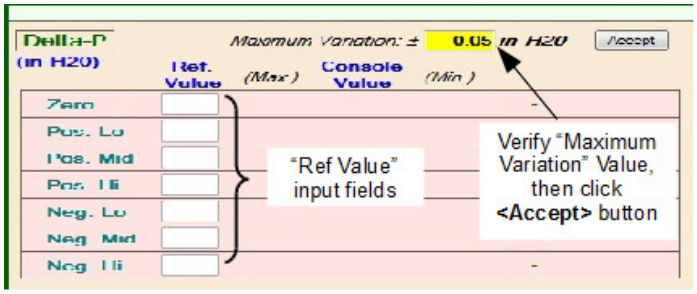
iii) Proceed to audit the other thermocouples in a similar manner by subjecting the thermocouple being audited and the reference temperature device, simultaneously, to the same temperature environment.

c) Audit Point 2:

i) Prepare a heated oil bath or other means to simultaneously subject the thermocouple(s) and the temperature reference device to the same temperature environment at a temperature at or near the expected stack gas.

ii) When the reference device reading is stable, enter the temperature in the "Ref Value" field for each thermocouple being audited. After each reference value is enter, the "Console Value" will then be displayed along with the message Pass or Fail and the difference between the stack thermocouple and the reference device measurements.

Note: If any thermocouples do not pass the audit, verify that all thermocouple signal connections have been properly made. If the sensor and signal cabling appear to be in order, the sensor must be recalibrated

	following the procedure provided in the Meter Calibration section.
	5) Delta P Audit a) Verify that the Maximum Variation value is correct. When ready, click Accept to activate the Ref. Value fields. b) Zero Point Audit: i) Configure a syringe, tubing and Pressure Reference Device and connect the equipment to the +Delta P quick connect port fitting on the instrument front panel. ii) Adjust the syringe plunger until the Pressure Reference Device indicates 0 – 0.2 in. H_2O (0 – 5 mm Hg). iii) When the reference meter is stable, enter the reference meter value in the Zero "Ref. Value" field. The results of the audit will be displayed with the message "Pass" or " -----". **Note: If the sensor doesn't pass, check the audit devices and connections, verify that there are no leaks in either the audit devices or the XC-5000 pneumatic connections between the front panel quick connect fitting and the pressure sensor, then retest. If the result is still not within audit specifications, please contact Apex Customer Support.** c) Positive Low Pressure Audit: i) Adjust the syringe plunger until the

Pressure Reference Device indicates between 1 and 1.5 in. H_2O (25.4 –38.1 mm Hg).

ii) When the reference meter is stable, enter the reference meter value in the Pos. Lo "Ref. Value" field.

iii) The results of the audit will be displayed with the message "Pass" or " -----".

d) Positive Mid Pressure Audit:

i) Adjust the syringe plunger until the Pressure Reference Device indicates between 2 and 2.5 in. H_2O (50.8 – 63.5 mm Hg).
ii) When the reference meter is stable, enter the reference meter value in the Pos. Mid "Ref. Value" field.
iii) The results of the audit will be displayed with the message "Pass" or " -----".

e) Positive High Pressure Audit:

i) Adjust the syringe plunger until the Pressure Reference Device indicates between 4 and 4.5 in. H_2O (101.6 – 114.3 mm Hg).
ii) When the reference meter is stable, enter the reference meter value in the Pos. High "Ref. Value" field.
iii) The results of the audit will be displayed with the message "Pass" or " -----".

f) Negative Low Pressure Audit:

i) Move the tubing/syringe/Reference Pressure Device apparatus to the – Neg Delta P port and adjust the syringe plunger until the Pressure

	Reference Device indicates between 1 and 1.5 in. H_2O (25.4 – 38.1 mm Hg). (**Note: A positive pressure must be generated in order to obtain the proper sensor response.)** ii) When the reference meter is stable, enter the reference meter value in the Neg. Lo "Ref. Value" field. iii) The results of the audit will be displayed with the message "Pass" or " -----". g) Positive Mid Pressure Audit: i) Adjust the syringe plunger until the Pressure Reference Device indicates between 2 and 2.5 in. H_2O (50.8 – 63.5 mm Hg). ii) When the reference meter is stable, enter the reference meter value in the Neg. Mid "Ref. Value" field. iii) The results of the audit will be displayed with the message "Pass" or " -----". h) Positive High Pressure Audit: i) Adjust the syringe plunger until the Pressure Reference Device indicates between 4 and 4.5 in. H_2O (101.6 – 114.3 mm Hg). ii) When the reference meter is stable, enter the reference meter value in the Neg. High "Ref. Value" field. iii) The results of the audit will be displayed with the message "Pass" or " -----".

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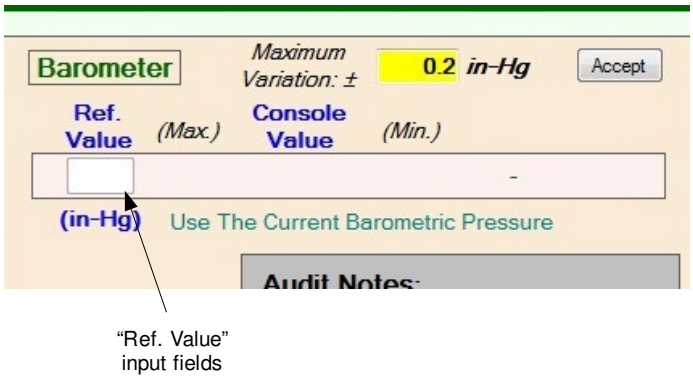
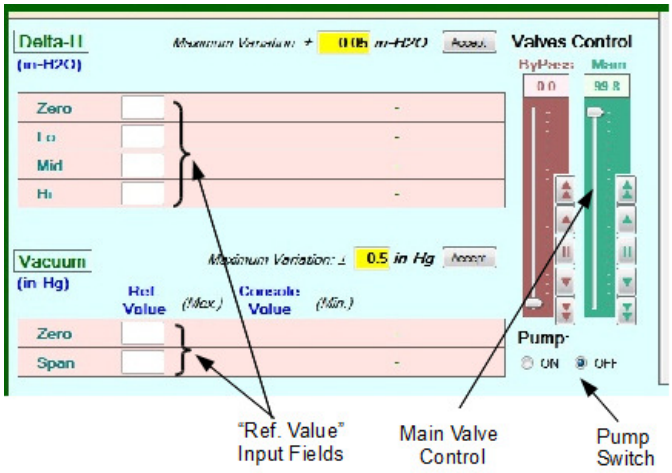


6) Barometric Pressure Sensor Audit
   a) Verify that the Maximum Variation field is displaying the correct value. Click Accept to activate the Ref. Value field.
   b) Obtain the current local barometric pressure.
   c) Input that value into the "Ref. Value" field.
   d) The results of the audit will be displayed with the message "Pass" or " -----".



7) Delta H Audits
   a) Verify that the Maximum Variation field is displaying the correct value. Click Accept to activate the Ref. Value field.
   b) Connect the sample pump to the Pump quick connect on the front panel of the XC-5000 Console.
   c) Configure a control valve with a Reference Pressure Device and connect the apparatus to the Sample Inlet Port.
   d) Zero Point:
      i) Close the control valve and verify that the Reference Pressure Device is reading 0 in. H_2O.
      ii) Enter the Reference Pressure Device reading into the "Ref. Value" field.
      iii) The results of the audit will be displayed with the message "Pass" or " -----".
   e) Lo Point:
      i) Close the Console Fine Control Value and Open the Console's Main Control Valve.
      ii) Turn the sample pump on and slowly close valve attached the

	sample inlet until the desired pressure is attained, e.g., approximately 5.4 – 6.75 in. H_2O (137.2 – 171.4 mm H_2O). iii) Allow the Reference Pressure Device reading to stabilize, then enter that reading into the "Lo" Ref. Value field. iv) The results of the Lo Delta H audit will be displayed with the message "Pass" or " -----". **Note: If the audit of the Lo point or any subsequent Delta H test point does not pass, a leak in the pneumatic system between the Reference Pressure Device and the Delta H pressure taps is indicated or the Delta H sensor needs to be recalibrated.** f) Mid Point: i) Close the control valve until the pressure reading is between 10.8 and 13.5 in. H_2O. ii) Allow the Reference Pressure Device reading to stabilize, then enter that reading into the "Lo" Ref. Value field. iii) The results of the Mid Delta H audit will be displayed with the message "Pass" or " -----". g) Hi Point: i) Close the control valve until the pressure reading is between 21.6 and 24.3 in. H_2O. ii) Allow the Reference Pressure Device reading to stabilize, then enter that reading into the "Lo" Ref. Value field. iii) The results of the Hi Delta H audit will be displayed with the message "Pass" or " -----".

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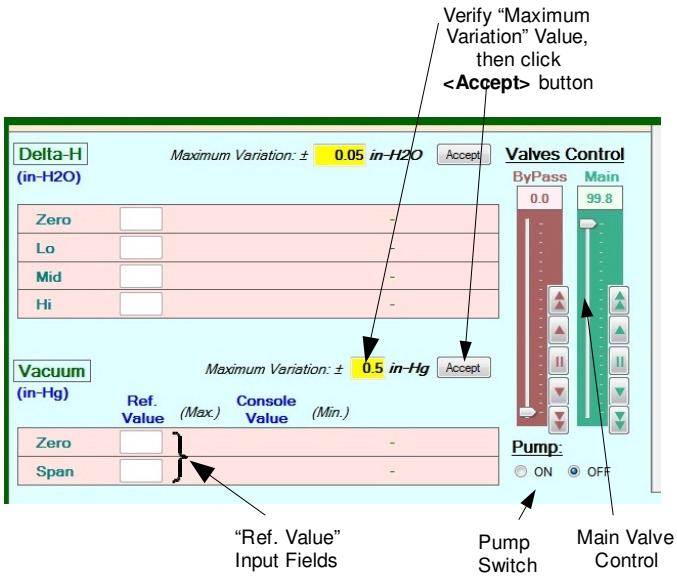

8) Vacuum Sensor Audit
   a) Verify that the Maximum Variation field is displaying the correct value. Click Accept to activate the Ref. Value field.
   b) Connect the sample pump to the Pump quick connect on the front panel of the XC-5000 Console.
   c) Configure a control valve with a Reference Pressure Device and connect the apparatus to the Sample Inlet Port.
   d) Zero Point:
      i) Close the control valve and verify that the Reference Pressure Device is reading 0 in. H_2O.
      ii) Enter the Reference Pressure Device reading into the "Ref. Value" field.
      iii) The results of the audit will be displayed with the message "Pass" or " -----".
   e) Hi Point:
      i) Turn the pump on.
      ii) Completely close the control valve until the pressure reading reaches a maximum delta H. The reading should be approximately 27 in. H_2O at an ambient barometric pressure of 29.92 in. H_2O (760 mm Hg).
      iii) Allow the Reference Pressure Device reading to stabilize, then enter that reading into the "Hi" Ref. Value field.
      iv) The results of the Hi Vacuum audit will be displayed with the message "Pass" or " -----".

Note: If the audit of the Vacuum audit doesn't pass, a leak in the pneumatic system between the Reference Pressure Device and the Delta H pressure taps is indicated or the Vacuum sensor needs to be

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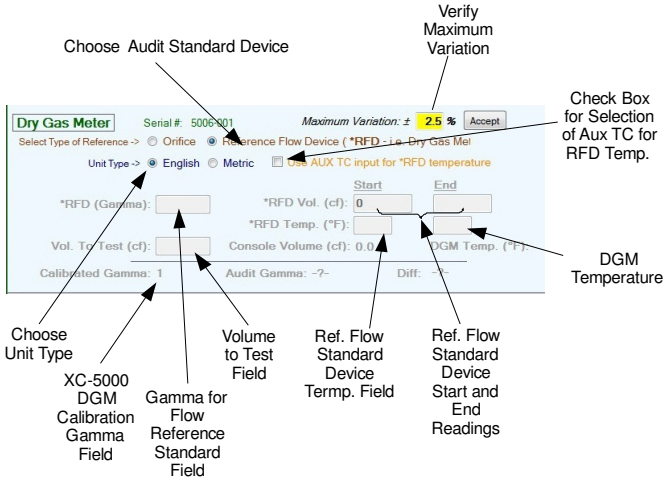
	recalibrated.



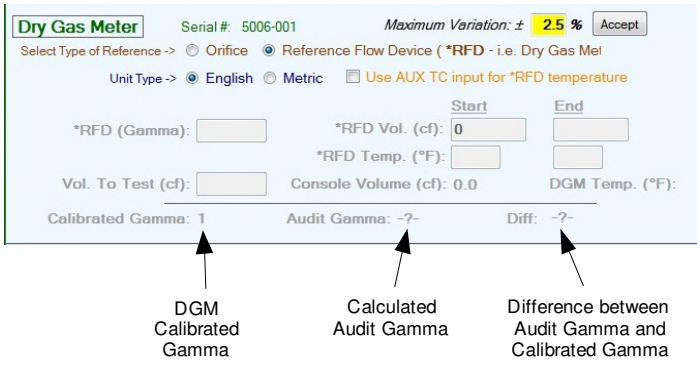
9) Dry Gas Meter

Note: At present, the audit can must be performed using a Wet Test Meter. The functionality to allow other types of flow reference device (RFD) such as an orifice set is being added at a later date.

a) Enter all system parameters into the Audit menu as follows:
   i) Maximum Variation – verify that the value is correct, then click the Accept button to activate the user input fields in this menu.
   ii) Verify that the desired Units of Measurement radio button is selected.
   iii) Click the radio button for Reference Flow Device.
   iv) Enter the Reference Flow Device meter's Gamma.
   v) Enter the Volume to Test.
   vi) Enter the Start Volume for the Reference Flow Device (typically 0).
   vii) Enter the XC-5000 DGM Gamma from the most recent meter calibration.

b) Connect the RFD to the Inlet Sample Port on the front panel of the XC-5000. (Currently, only the RFD option is available.)

c) To allow the Console to monitor and record the gas temperature measured at the outlet of the Flow Reference Device, connect the temperature sensor output to the Aux.

<table>
<tr>
<td> 
</td>
<td>Thermocouple input on the front panel of the XC-5000 and click the check box for the “Aux TC input for RFD temperature.”
d) Insert a valve between the RFD and the front panel quick connect in order to adjust the vacuum to the desired level.
e) Turn on the sample pump and adjust valve to attain the highest delta H observed during the test series.
f) The test will continue until the user specified Test Volume is measured by the Console Dry Gas Meter.
g) Enter the total volume measured by the Reference Flow Device in the “Reference Flow Device End” field.

Note: The audit difference result will be calculated by the software based on the difference between the Gamma calculated from the audit results (“Audit Gamma”) and the Gamma obtained from the periodic DGM calibration.</td>
</tr>
<tr>
<td> 
</td>
<td>After all required audits are complete, click Save Audit. A File Explorer window will open to allow the file to be saved to the desired location on the user’s computer. Audit files are saved with the .csv extension.

The audit file can also be saved to a .jpg file by clicking Print To File.

By default, the audit file is saved to the c:\apex_5 folder.</td>
</tr>
</table>

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