Protocol
CCM - International Key Comparison in Absolute Pressure (1 Pa to 10 kPa)

<<CCM.P-K4.2012>>

Version 9.0

Pressure and Vacuum Group
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Table of Contents

1. INTRODUCTION

At the combined meeting of the CCM HP and CCM LP working groups in 2008 it was decided that there was a need to hold a new round of key comparisons in absolute pressure. It has been nearly 10 years since the last key comparison in pressure that had spanned the range of 1 Pa to 1000 Pa. Additionally, since that last key comparison in absolute pressure, CCM.P-K4, new national standards have been developed. These standards include manometers and non-rotating Force-balanced Piston Gauge (FPG) that operate between 1 Pa to 15 000 Pa absolute. It was decided that NIST's experience in the previous low pressure comparison and detailed knowledge in the design and construction of high-stability resonance silicon gauge transfer standard packages made it ideally suited to be the pilot. At the combined CCM HP and LW working group meeting in Berlin, 2011, it was re-confirmed that NIST would complete constructing and testing of a two new transfer standard packages capable of absolute pressure measurements spanning the extended range of 1 Pa to 10 000 Pa.

2. OBJECTIVE

The purpose of the comparison is to determine the relative agreement between absolute pressure standards of the participating laboratories in the pressure range of 1 Pa to 10 000 Pa (absolute, N_2 gas), to determine a key comparison reference value (KCRV), and to determine degree of equivalence of the participation laboratories to the KCRV. To achieve this goal a transfer standard has been developed by the pilot laboratory that consists of four pressure transducers with the following ranges; 133 Pa, 133 Pa, 10 000 Pa, and 10 000 Pa. The transfer standard package utilizes differential pressure transducers and an integrated ion vacuum pump to achieve the necessary reference pressure for the absolute measurements. Four transducers have been selected for reasons of redundancy and resolution to cover the three decades of pressure. The pressures selected for this comparison are: 1, 3, 7 (optional), 10, 30, 70 (optional), 100, 300, 700(optional), 1000, 3000, 7000, 10 000 Pa.

3. PARTICIPATING LABORATORIES

The following laboratories are the participants in this comparison, listed alphabetically along with coordinators for contacts.

Table 1. List of Participating Laboratories.

Participant	Address	Telephone/Fax	Email Address	Contact
AFRIMETS NMISA (South Africa)	NMISA ATTN: Cherie Korasie Private Bag X34 Lynnwood Ridge 0040, South Africa	Tel: +27 12 841 4936 Fax: +27 867160988	ckorasie@nmisa.org	Cherie Korasie
APMP NMIJ (Japan)	NMIJ ATTN: Tokihiko Kobata AIST Tsukuba Central 3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, Japan	Tel: +81-29-861-4378 Fax: +81-29-861-4379	tokihiko.kobata@aist.go.jp	Tokihiko Kobata
COOMET VNIIM	VNIIM ATTN: Irina Sadkovskaya Moskovsky pr., 19, St. Petersburg 190005 Russia	Tel: +7 812 251 59 77 Fax: + 7 812 251 37 89	siv@vniim.ru	Irina Sadkovskaya

EURAMET CMI	Czech Metrology Institute ATTN: Pražák Dominik Okruzni 31 63800 Brno Czech Republic	Tel.: +420 545 555 226 Fax: +420 545 555 183	dprazak@cmi.cz	Pražák Dominik
EURAMET PTB (Germany)	Physikalisch-Technische Bundesanstalt ATTN: Karl Jousten Abbestr. 2-12 D-10587 Berlin Germany	Tel: 49-30-3481-7262 Fax: 49-30-3481-7490	Karl.Jousten@ptb.de	Karl Jousten
(Pilot lab) NIST (U.S.A.)	NIST ATTN: Jay Hendricks 100 Bureau Dr Bldg. 217 RM B157 Gaithersburg, MD 20899-8364 U.S.A	Tel: 01 301-975-4836 Fax: 01 301-975-5969	jayh@nist.gov	Jay Hendricks
SIM CENAM (Mexico)	CENAM ATTN: Jorge Torres km 4.5 Carretera a los Cués 76241 El Marqués, Querétaro México	Tel: +52 442 211 0500 ext. 3609 Fax: +52 442 211 0568	jorge.torres@cenam.mx	Jorge C. Torres

4. ORGANIZATION OF THE KEY COMPARISON

Two nominally identical transfer standard packages have been developed for the comparisons. The comparison schedule, shown in Table 2, has been developed based upon desired timing from the individual laboratories and to minimize the time required for the comparison. One package, designated package **A** will remain at NIST to serve as control for the circulated package, designated package **B**. Should technical problems arise with circulated package **B**, the control package **A** may be brought into service at the discretion of the pilot as a backup unit. **Participant laboratories are required to notify the pilot laboratory if they did not receive the artifact by the target date of arrival. Participant laboratories are required to notify the pilot laboratory via email (one week in advance) if they are unable to ship the transfer standard on the target date of completion. All effort should be made to adhere to the schedule in order to minimize scheduling problems and to enhance the possibility for a timely completion of the comparison.**

Table 2. Organization of the Comparison

Laboratory	CCM 10 kPa Package	Target Date of Arrival	Target Date of Completion	Modes of Test
Pilot - NIST	**A,B**	January 7th 2012	April 30th 2012	Absolute, N_2
NMI 1 - PTB	**B**	May 21st 2012	June 30th 2012	Absolute, N_2
NMI 2 - CMI	**B**	July 16th 2012	September 7th 2012	Absolute, N_2
NMI 3 - NMIJ	**B**	September 17th 2012	November 20th 2012	Absolute, N_2
Pilot - NIST	**A,B**	November 30th 2012	January 18th 2013	Absolute, N_2
NMI 4 - CENAM	**B**	January 28th 2013	March 4th 2013	Absolute, N_2
NMI 5 - VNIIM	**B**	March 13th 2013	April 17th 2013	Absolute, N_2
NMI 6 - NMISA	**B**	April 29th 2013	June 3rd 2013	Absolute, N_2
Pilot - NIST	**A, B**	June 12th 2013	July 17th 2013	Absolute, N_2

5. DESCRIPTION OF TRANSFER STANDARD

The transfer standard consists of two parts: (1) a Pressure Transducer Package (PTP) and (2) a Support Electronics Package (SEP). The PTP (see Fig. 1) includes four differential transducers housed in a temperature-controlled enclosure, an ion vacuum pump and, necessary plumbing. The PTP has the following general characteristics:

Dimensions:	62 cm long x 58 cm high x 40 cm wide (48 cm wide with handles)
Weight:	~25 kg
Vacuum connections:	¼ inch female VCR
Nominal internal volume:	~120 cm^3 pressure side of V_2 (closed) and with V_3 and V_5 open ~550 cm^3 reference side of V_2 (closed)

The characteristics of the four transducers are summarized in Table 3.

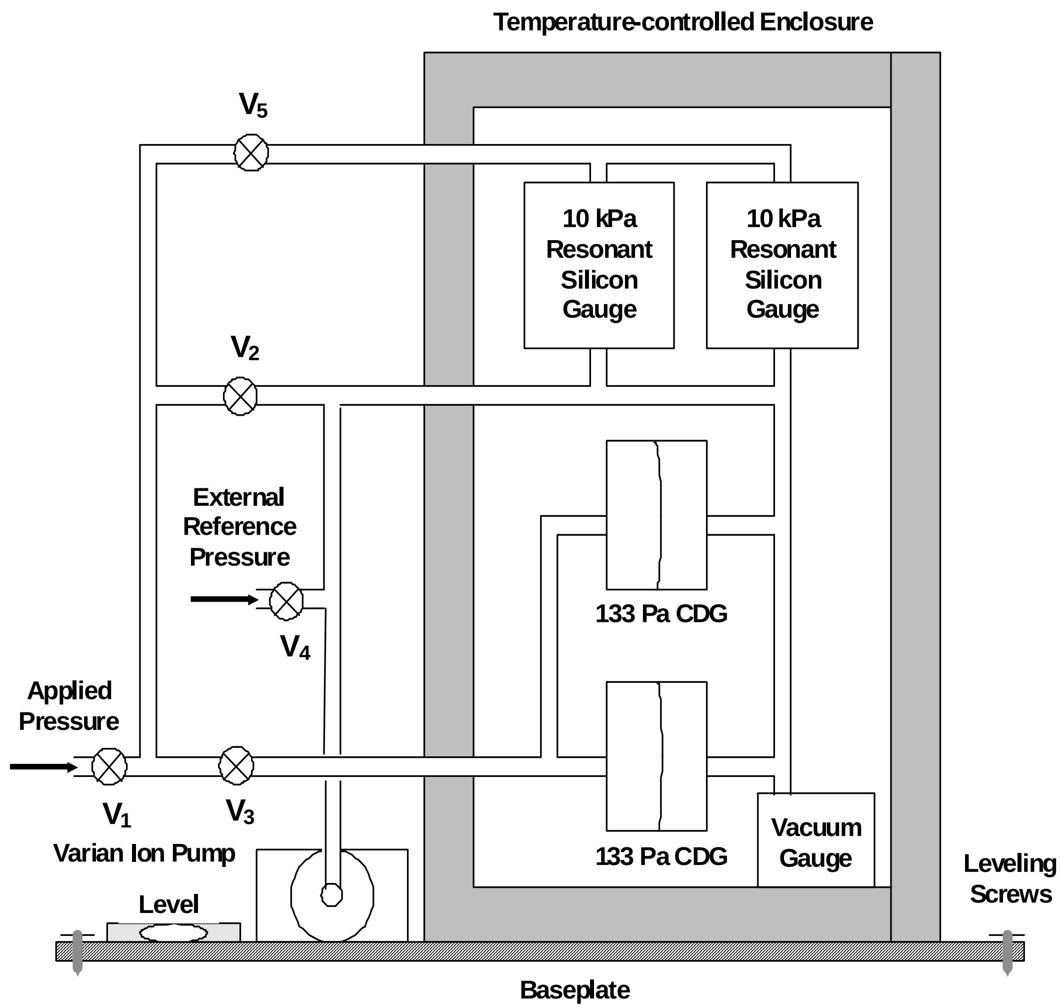


Figure 1. Schematic diagram of the pressure transducer package (PTP).

Table 3. Characteristics of the Transfer Standard Transducers.

Transducer Identifier	Sensor Type	Range (Pa)	Resolution (Pa)	Maximum Overpressure (Pa)
CDG1	Capacitance Diaphragm Gauge	133	10^{-4}	300*
CDG2	Capacitance Diaphragm Gauge	133	10^{-4}	300*
RSG1	Resonant Silicon Gauge	10,000	10^{-2}	**20,000****
RSG2	Resonant Silicon Gauge	10,000	10^{-2}	**20,000****

* Avoid exposing the CDG's to pressures > 150 Pa to 300 Pa by using isolation valve V_3.

**** Differential pressures > 0.5 atmosphere will damage the resonant silicon gauges.**

The SEP includes a Digital Voltmeter (DVM), signal conditioning electronics for the CDGs, display electronics for the reference vacuum gauge, temperature control circuitry for the transducer enclosure, and a controller for the ion vacuum pump. The SEP has the following electrical requirements:

Voltage: 100 to 120 Volts AC
Frequency: 50/60 Hz
Power Consumption: <0.5 kW

Additional information on the instruments and transducers are given in Appendix A.

6. TRANSPORTATION

Two custom cases have been constructed for shipment of the transfer standard. Case 1 (~ 77x66x79 cm) is used to ship the PTP as well as necessary signal cables, which connect it to the support electronics. Case 2 (~ 75x65x90 cm) contains the SEP which consists of an electronics rack which is permanently shock-mounted into the case and holds all necessary electronics needed to operate the PTP. This includes a rack-mounted computer with pull out keyboard and display. These shipping cases should be used for shipment or movement of the transfer standard between laboratories without exception. Each case is equipped with a set of recessed wheels (and a telescoping handle) to facilitate movement of the transfer standard within individual laboratories. All effort should be made to avoid subjecting the transducers and/or cases to mechanical shock during transport to minimize possible effects upon stability of the transducers.

When rolling the packages on the supplied wheels, care should be taken when tipping the package up or back-down. Always have a second person hold the handles on far end case while tipping up or down the package. A second person is very important to assists in **slowly** lowering the far end of the package to prevent the case from "snapping down" to the floor causing unnecessary shock to the gauges. **NOTE: The package weight is not centered over the telescoping handle so it does not provide the necessary leverage to lower the package gently.** The packages should not be transported up or down steps on the supplied wheels.

6.1 Shipping of Transfer Standard

On arrival, the transfer standard shall be inspected by the laboratory personnel for damage and completeness of its components. Availability of the ATA Carnet should be checked by the participating laboratory, and in a case of its absence, the pilot laboratory should be immediately informed. The arrival check report, included in Appendix B, shall be filled in and sent to the pilot laboratory and to the sending NMI by e-mail or fax. The instrument shall only be unpacked and handled by qualified personnel. If excessive damage to a shipping case is noticed, this should also be reported immediately to the shipping company, along with a photograph of the damage.

Completeness of all components is to be checked again before shipment of the transfer standard to the next participant. Participants shall complete the departure check report provided in Appendix B and send to the pilot laboratory and to the destination laboratory by e-mail or fax before shipping the Transfer Standard.

Each participant is responsible for the transportation of transfer standard to the next participant according to the circulation scheme. The transport method (preferably Air Freight) should be chosen by the participant to deliver the transfer standard to the next participant safely and on time. All transfer standard parts should be carefully packed using original packing materials and containers.

For shipment, an ATA Carnet will be prepared. For countries not accepting an ATA Carnet (Please check with your authorities), Declaration Letters will be prepared which should relieve the temporary import of the transfer standard. Care should be taken that the ATA Carnet and the Declaration Letters **always** accompany the transfer standard when it travels.

To avoid loss of the ATA Carnet, the following procedure must be followed:

- When sending the transfer standard to an ATA Carnet accepting country, the ATA Carnet is put into the outside envelope attached to the PTP. Additionally, a copy of the ATA Carnet is put into the outside envelope attached to the SEP. Declaration Letter(s) shall be stored at all times in the drawer of the SEP when shipping to an ATA Carnet country.
- When sending the transfer standard to a non-ATA Carnet country, (i.e. CENAM or NIM), the respective Declaration Letter is put into the outside envelope of the PTP. A copy of the Declaration Letter is put into the outside envelope attached to the SEP and the ATA Carnet is stored in the drawer of the SEP.

6.2 Calibration and Shipment Costs

Each participant bears the costs for its own measurements, transport costs to the next participant, any customs charges, and costs due to loss or damage of transfer standard within its country.

7. SETUP AND MEASUREMENT PROTOCOL

The protocol should be followed as closely as possible to facilitate proper comparison of data sets from participating laboratories. In the event that no excessive damage is visible, transport the cases to the laboratory for installation on the participant's pressure standard.

7.1 Initial Setup of the Transfer Standard

7.1.1 Unpacking the Transfer Standard

Case 1, shown in Figure 2, is of the clam-shell type to ease the unpacking and repacking of the pressure transducer package (PTP). With Case 1 sitting upright, as indicated by the arrows (pointing up) on the sides of the case, the fasteners should be unlatched and the top sections of the case removed by lifting upward. The PTP should be inspected to ensure that no obvious damage has occurred during shipment. The PTP should then be lifted from the bottom of Case 1 by <u>two</u> people, using aluminum baseplate "handles" and placed on a hard flat surface.

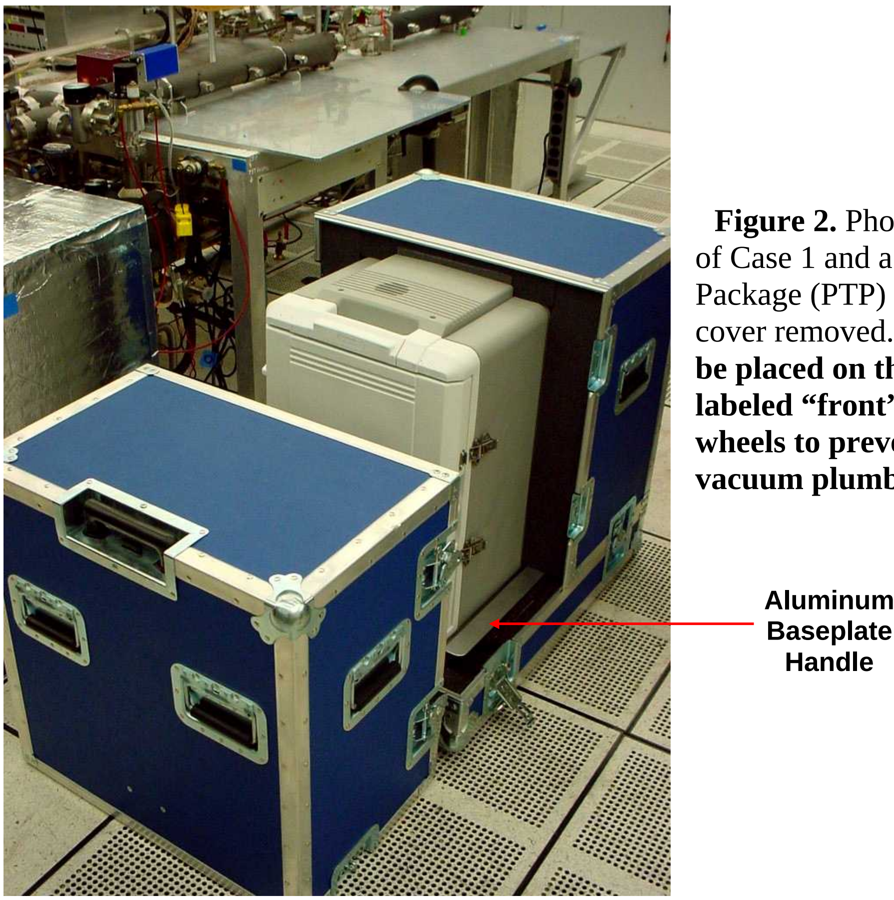


Figure 2. Photograph showing clam-shell of Case 1 and a typical Pressure Transducer Package (PTP) with the front clamshell cover removed. **NOTE: The PTP should be placed on the base with its door, labeled "front", over top of the recessed wheels to prevent excess stress on the vacuum plumbing.**

Case 2, shown in Fig. 3, contains the Support Electronics Package (SEP) for the PTP. The SEP contains a built-in electronics rack that is permanently shock mounted into Case 2. **NOTE: The front and rear covers of the case shall always be removed while in use to allow air cooling and operation of the rackmount computer system.** As this system produces a significant amount of heat, do not place the rear exhaust fans blowing towards the PTP, vacuum system, or NMI Standard.

7.1.2 Installation of the Transfer Standard on the Participant's Pressure Standard

The PTP shall be installed near the pressure standard of the participating laboratory so that its baseplate is mounted on a **level, sturdy, stable, low-vibration surface**. Open the door of the PTP and inspect the interior. Foam shipping blocks above the CDG1 and CDG2 shall be removed and stored in the bottom drawer for re-insertion prior to next shipment. Because the resonant silicon gauges in the PTP are highly sensitive to changes in orientation the **three leveling screws on the baseplate** shall be adjusted so that the bubble in each of two orthogonal levels is centered to within $\pm$ 1 division. The maximum sensitivity of the resonant silicon gauges to tilt in transfer package **B** is 0.011 Pa/division (**A** is 0.012 Pa/division) about an axis parallel to the handles of the baseplate (front to back tilt). The tilt sensitivity of the gauges about the other axis (side to side tilt) is only 0.0001 Pa/division for package B and (A is 0.0003 Pa/division).

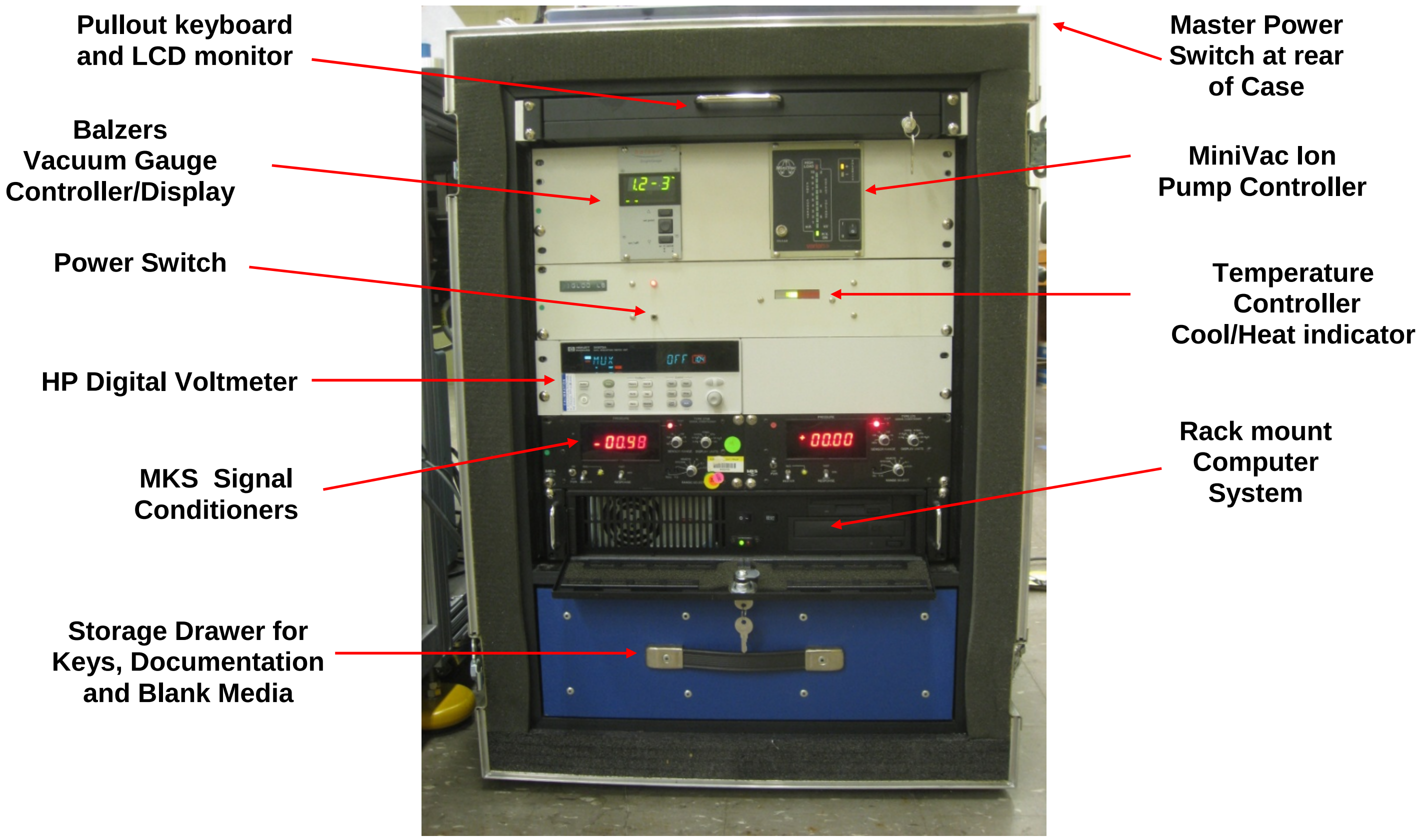


Figure 3. Photograph of Case 2 (SEP) with its front/back covers removed. The support electronics for the PTP are shock-mounted inside Case 2. Note: the placement of controllers may have changed.

Case 2, shown in Figure 3, contains the SEP and can be located in any convenient location within two meters of the PTP. The cabling from the PTP shall be connected to the support electronics in the SEP **before electrical power is applied (110 VAC 50 Hz to 60 Hz only!)**. **NOTE: Each participant must provide compatible 110 VAC 50 Hz to 60 Hz power.** A schematic of the proper connections between the SEP and the PTP are given in Figure 4. **Color-coded tape** is used on the cables and on or near the instrument connectors to facilitate the identification of matching connectors. Connect all eight interconnecting cables from the PTP to the SEP before powering on the SEP (see Section 7.1.3).

The PTP is shipped with its internal plumbing under vacuum with isolation valves V_1 and V_4 closed, bypass valve V_2 open, and isolation valves V_3 and V_5 open (see Fig. 1). The purpose is to protect the resonant silicon gauges against overpressure in case of a leak during shipment. Connect the NMI pressure standard to isolation valve V_1 (¼ inch female VCR) of the PTP using suitable vacuum plumbing (internal diameter should be **at least as large as** that for the ¼ inch VCR fittings) and evacuate the plumbing between the pressure standard and V_1 to a pressure of ~ 10^{-3} Pa before opening V_1.

7.1.3 Initial power up of the Transfer Standard

IMPORTANT: Connect to 100V to 120 V and 50/60 Hz ONLY!
(Power consumption less than 500 watts)

The PTP and SEP shall be in the laboratory for a minimum of 24 hours prior to power up to allow for temperature stabilization with the laboratory environment. (When the packages arrive at your NMI, immediately store them in the lab where they will be set up and used). Before turning on the electrical power to the SEP, **check the power switch on the MiniVac ion pump controller to ensure that it is turned off (IMPORTANT FOR SAFETY).** With cabling connected in accordance with Fig. 4, turn on the electrical power to the SEP using the master

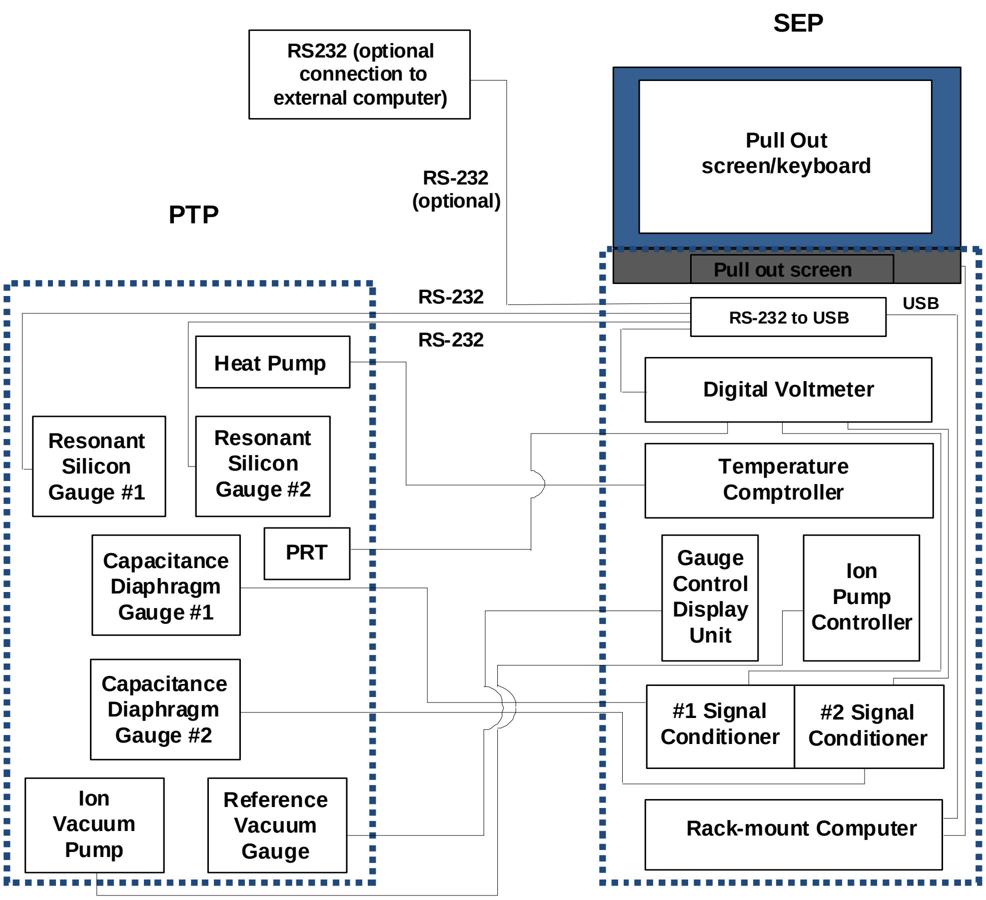


Figure 4. Cable interconnections between the pressure transducer package (PTP) and the support electronics package (SEP).

switch at the rear of case. There will be an audible “beep” from the temperature controller[1] if it is turned on. Upon power up, verify the following:

1. Volt meter = ON
2. Temperature controller power switch = ON (up position)
3. Balzers vacuum gauge = ON (switch in back if not)
4. MiniVac ion pump = OFF
5. CDG1 and CDG2 (power = ON, heater = OFF, response = SLOW, sensor range = 1, range select = X1, display units = kPa

Check the Balzers vacuum gauge controller that will display the residual pressure in the internal plumbing of the PTP. This value should be recorded in the arrival check report (Appendix B). If the vacuum gauge controller displays a reading greater than 0.1 Pa, evacuate the PTP with a suitable high vacuum pump (turbo pump, liquid nitrogen cooled diffusion pump) through valve V_1 (may require initial rough pump out). Once pressure is below 0.1 Pa, close valve V_1 and turn on the MiniVac ion pump (see Fig. 3). The maximum pressure for starting the ion-pump is 0.5 Pa; however starting at this pressure will require a longer time to reach a low reference pressure and will shorten the lifespan of the pump. Check the high load light on the MiniVac ion pump controller. If the high load light on the MiniVac ion pump controller remains on for more than 60 seconds turn off the ion vacuum pump, open isolation valve V_1 and externally evacuate the PTP to a lower pressure. If an error message is displayed by the Balzers controller check page 15 of the Operating Manual—located in the storage drawer in the SEP.

With valve V_1 (and V_4) closed and valves V_2, V_3, and V_5 open, **allow the transfer standard to equilibrate with the ion-pump on for a minimum period of 48 hours before proceeding with the calibration.** At the pilot lab, typical low pressure values of 1.4 $x10^{-3}$ Pa (package **A**), and $1.9x10^{-3}$ Pa (package **B**) were seen after pumping for about 1 week. While waiting for the transfer standard to equilibrate and pump out, proceed with initial testing/checkout and become familiar with the operation of the computer and the data acquisition software.

The temperature controller (in SEP) has an indicator bar showing illuminated green LEDs when it is cooling and red LEDs when it is heating. The temperature is perfectly balanced (at the control set point) when no LEDs are illuminated. NOTE: it is rare that the controller is neither heating nor cooling (no LEDs illuminated), so if no LEDs are illuminated, ensure the controller is powered on. When the temperature is in control, the number of blinking LED’s will remain constant with usually one or two green LEDs (this cooling is required due to internal electronics heating). NOTE: if the controller indicator is off-scale in either direction after 12 hours (overnight), the system may need to be reset. To reset, turn off the temperature controller power switch and open the door on the PTP. Allow the temperature to return to ~23 ^{o}C then close the door and turn the power switch back on. It may be possible for the lab temperature to be too cool or hot for the system to control. If the problem persists after a reset, contact the pilot lab.

[1]**NOTE:** The temperature controller has an alarm to alert the user if failure of the fan motor on the temperature controller is imminent or has already occurred. A continuous high pitch alarm indicates that the fan motor is not operating normally—a periodic “beep”, once per second, indicates the fan motor has stopped. If so, contact NIST for further instructions, a spare motor located in the laptop storage drawer in the SEP.

7.2 Data Acquisition Software

This section describes the connection of the computer to the transfer standard, the initialization of the software, use of the software, and diagnostics to ensure the system is working properly. The computer and electronics shall be setup as shown in Fig. 4. Ensure that cables between the SEP and PTP are connected (see section *7.1.2*) and all electronics are powered on (see section *7.1.3*).

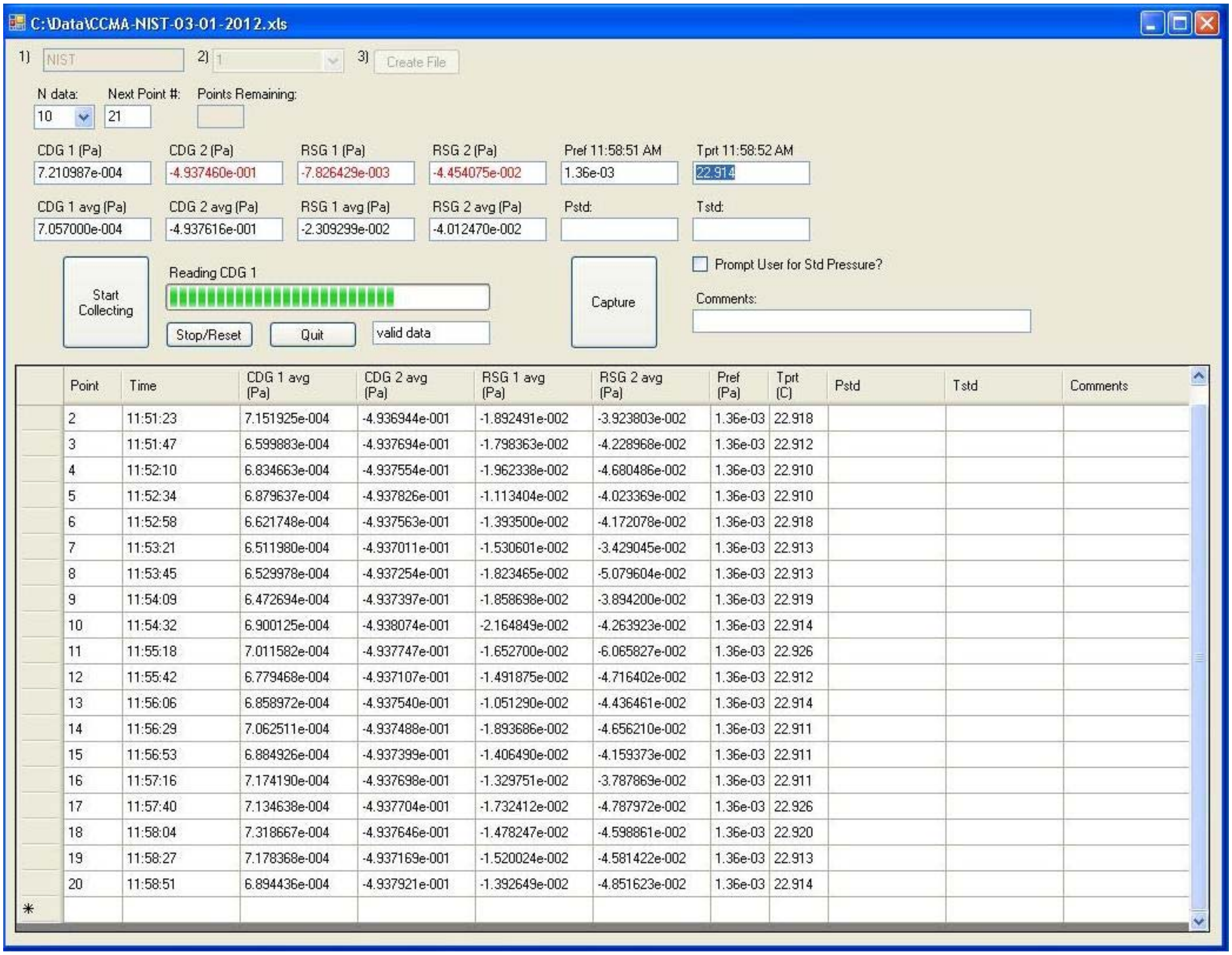
WARNING: Any attempt to change the computer's default settings (other than date and time), add software, or alter the current settings of the Windows operating system may corrupt the operation of the existing software and lead to unnecessary delays. ***At no time should the systems network connection be connected to the host institution.***

Turn the computer on (located in the bottom of the electronics rack) by unlocking the front panel (keys located in bottom drawer) and pressing the momentary switch. Close and relock the front panel to ensure the air filter is correctly installed. Unlock and pull out the computer screen/keyboard from its top storage drawer in the SEP (keys located in bottom drawer). The computer will start the operating system (Windows XP). Log into the "CCM2012" account with the password (supplied separately).

To start the data collection program, use the desktop short cut called "CCM 2012" A sample screen of the data acquisition software is shown in Fig. 5. When the software is started, the user is asked for an *Institution Name*. Once entered, it will wait for the user to create a file by selecting a run number and pressing "Create File". Once a file is created, the system automatically enters an "idle" state in which readings of CDG1, CDG2, RSG1, RSG2, etc. are taken continuously and displayed in the upper six boxes shown in Fig. 5. The only way to exit this state is by terminating the program. You will hear the click of relays in the voltmeter during this idle state which is completely normal. Each time the pressure is updated in one of the boxes, the color of the text alternates between red and black. The program also maintains a running average of each gauge and displays this value in the lower boxes for each gauge.
To ensure that all connections are properly made and that no catastrophic failures have occurred during shipment examine the output of the program as follows:

1. Observe the readings in the six boxes shown near the top of Fig. 5 (CDG1, CDG2, RSG1, RSG2, etc.). The first four readings (in Pa), which correspond to the pressure transducers, should indicated a pressure less than 10 Pa. If the readings of CDG1 and CDG2 are greater than 0.1 Pa verify that the display of the MKS controllers also indicate a similar reading.
2. The temperature reading (Tprt) should be reasonable (the thermal enclosure has been thermostated to operate at a temperature of 23.25 $\pm$ 0.3 ^{o}C for package B and 22.9$\pm$ 0.3 ^{o}C for package A after equilibration for 24 hours)
3. The internal pressure reading (Pref) should ***approximately*** correspond to the value indicated by the Balzers control unit.

Note: The program can be set up to take large amounts of data to monitor the pump down of the system and the temperature stability of the transfer standard. For ~10 hours of data, set "N Data" = 1500 and hit "Start Collecting" button.



Point	Time	CDG 1 avg (Pa)	CDG 2 avg (Pa)	RSG 1 avg (Pa)	RSG 2 avg (Pa)	Pref (Pa)	Tprt (C)	Pstd	Tstd	Comments
2	11:51:23	7.151925e-004	-4.936944e-001	-1.892491e-002	-3.923803e-002	1.36e-03	22.918			
3	11:51:47	6.599883e-004	-4.937694e-001	-1.798363e-002	-4.228968e-002	1.36e-03	22.912			
4	11:52:10	6.834663e-004	-4.937554e-001	-1.962338e-002	-4.680486e-002	1.36e-03	22.910			
5	11:52:34	6.879637e-004	-4.937826e-001	-1.113404e-002	-4.023369e-002	1.36e-03	22.910			
6	11:52:58	6.621748e-004	-4.937563e-001	-1.393500e-002	-4.172078e-002	1.36e-03	22.918			
7	11:53:21	6.511980e-004	-4.937011e-001	-1.530601e-002	-3.429045e-002	1.36e-03	22.913			
8	11:53:45	6.529978e-004	-4.937254e-001	-1.823465e-002	-5.079604e-002	1.36e-03	22.913			
9	11:54:09	6.472694e-004	-4.937397e-001	-1.858698e-002	-3.894200e-002	1.36e-03	22.919			
10	11:54:32	6.900125e-004	-4.938074e-001	-2.164849e-002	-4.263923e-002	1.36e-03	22.914			
11	11:55:18	7.011582e-004	-4.937747e-001	-1.652700e-002	-6.065827e-002	1.36e-03	22.926			
12	11:55:42	6.779468e-004	-4.937107e-001	-1.491875e-002	-4.716402e-002	1.36e-03	22.912			
13	11:56:06	6.858972e-004	-4.937540e-001	-1.051290e-002	-4.436461e-002	1.36e-03	22.914			
14	11:56:29	7.062511e-004	-4.937488e-001	-1.893686e-002	-4.656210e-002	1.36e-03	22.911			
15	11:56:53	6.884926e-004	-4.937399e-001	-1.406490e-002	-4.159373e-002	1.36e-03	22.911			
16	11:57:16	7.174190e-004	-4.937698e-001	-1.329751e-002	-3.787869e-002	1.36e-03	22.911			
17	11:57:40	7.134638e-004	-4.937704e-001	-1.732412e-002	-4.787972e-002	1.36e-03	22.926			
18	11:58:04	7.318667e-004	-4.937646e-001	-1.478247e-002	-4.598861e-002	1.36e-03	22.920			
19	11:58:27	7.178368e-004	-4.937169e-001	-1.520024e-002	-4.581422e-002	1.36e-03	22.913			
20	11:58:51	6.894436e-004	-4.937921e-001	-1.392649e-002	-4.851623e-002	1.36e-03	22.914			

Figure 5. Data acquisition software screen (typical) at zero pressure.

7.2.1 Acquisition Technique/Method

To initiate a data collection, select <u>one</u> of the following methods:

- **a) "Start Collecting" button**
- **b) "Capture" button**
- **c) RS232 commands**

Total data collection time for each method is about 24 seconds. Detailed description of how the data is collected and time required for each gauge in included in APPENDIX C.

a) "Start Collecting" option:

To use this method: Select the number of data points to collect in succession (using the "N Data:" selection), select if the user will manually enter their NMI's data (using the "prompt user for Std Pressure?" check box), and click the "Start Collecting" button. If the manual input is selected, the program will require the value read/measured for the NMI's standard pressure and temperature to be recorded and entered in a popup box before starting the next point. The program will not idle or take data until the value is entered. For each data point, the RSG/CDGs will all be read followed by the PRT and reference pressure via Balzers gauge.

b) “Capture” Option:
Pressing this button captures the ***previous*** ~24 seconds of data. As with “start collecting”, if the user indicates manual input, a pop-up box will prompt the user for the reading of the user’s primary standard pressure and temperature. The program will capture the previous 24 seconds of RSG/CDG data and will immediately measure the PRT and reference pressure. This method is useful if you wish to better sync the standard’s data collection with the package to ensure they are taking data at the same time (user will press the capture button as soon as the standard has finished measuring). If this method is used, the “capture” button must be pressed *N* times to record *N* data points.

c) Data transfer over the RS232 option:
In this option, data is recorded when a command is sent from a user’s computer over the RS-232 bus. The user can connect a “twisted” RS-232 cable from their computer to com port #4 in the back of the SEP. The program will automatically check this port for primary standard pressure and temperature (when accompanied with proper set of characters). Only one data point will be recorded for each command sent. For additional information see Appendix D for the specific format that must be used for this option to work. When using this option, the program will only use the previous ~24 seconds of data for the readings of the CDGs and RSGs, with some slight modifications to deal with what happens to CDG readings that are nearly complete/or started when pressure is received. Also included are an optional “hold” command that can be issued over the RS232 port to tell the program to stop idling and wait/hold current values (used to align the 24 second data collection window with the NMI’s pressure standard) and an optional “clear” command to clear the averages and restart the 24 seconds of data taking. It is important to wait at least 24 seconds between user send commands, otherwise the CDGs and RSGs will not be updated and the program will ignore the request.

7.2.2 Additional Software Features
The “Stop/Reset” button can be used to clear the data averaging or to stop a current set of recording data. Comments can be typed into the comments box and will be saved into the excel output file. **NOTE: It is suggested that users add comments if your NMI is planning to add the readings of the standard after the run is completed.** Comments can be anything from corresponding data point numbers, target pressures, or any generic text. After completing the calibration run, click on the “Quit” button to return the computer to its desktop screen. **NOTE: If the program is not closed before the next data run a new data file will not be created. Close the program after each run is completed.**

7.2.3 Data Offload Procedures
The data files are stored on the computer in the “C:\Data\” folder with the following filename format:
“CCM#-Institution Name-MM-DD-YYYY.xls”
Where # is either A for Package A or B for Package B, Institution Name is the name inputted by the user when the program is started, and MM-DD-YYYY is the date (MM=Month, DD=Day, YYYY=Year). The current filename is displayed on the program’s title bar as seen on Figure 5 (blue bar across top of screen). If you wish to change the file name, please do so after completing the data capture and closing the program. Once all data collection has been completed, save/write your data files to an external source (CD-R/RW is recommended, blank media provided in bottom drawer) and back-up your data to your NMI’s computer. Finally, verify values of NMI’s pressure standard are included or added (if taken separately) and that any necessary corrections are applied (i.e. Head or Mercury Vapor corrections) before emailing final version of all files to the pilot lab. To protect each

NMI's data, NIST requires that each NMI remove/delete your data files from the computer before shipping to the next NMI.

7.3 Procedure for Calibration of the Transfer Standard

The transfer standard should be calibrated with nitrogen gas by comparison with the pressure standard of the participating laboratory at the following nominal pressures: 1, 3, 7(opt), 10, 30, 70(opt), 100, 300, 700(opt), 1000, 3000, 7000, 10000 Pa. Points labeled "opt" are not required; data may be taken at these points (7, 70, and 700 Pa) for comparison with data from the pilot laboratory. The actual pressures realized by the participant's pressure standard during the calibration should not differ from the cardinal point pressures by more than 2%. Please note that the pressure indicated by your NMI's standard must be within 2% of target even though the pressure indicated by the package might be outside of this value.

A mandatory **five calibration runs** should be carried out, with each run proceeding from lowest to highest pressures and each run taken on a different day. Additional calibration runs may be performed at the discretion of the participating laboratory but **only data from five runs** should be forwarded to the pilot laboratory for purposes of the comparison. Ideally, a reading of the participant's standard should be recorded at approximately the same time a set of readings of the transfer standard are recorded. This can be important for pressure standards that are pressure measurers (e.g., manometers) since the pressure may drift during the time required to record five repeat readings. This may not be an issue for pressure standards that are pressure generators (e.g., volume expansion systems) provided their temperature and hence the generated pressure does not change during repeat readings of the transfer standard.

The laboratories should operate their pressure standards at their normal operating temperature (NIST operates at a nominal 23.0^{o}C). A Reading of the NMI's temperature of the standard is required to be provided for each pressure point in order for the pilot lab to make the required thermal transpiration corrections. This will account for small temperature differences between the participant's pressure standard and the transfer standard.

Head corrections shall be referenced to the reference level line indicated on the PTP. NOTE: It is the participant NMI's responsibility <u>to make all corrections specific to your NMI's standard</u> (Head correction, Mercury Vapor Pressure, etc.) <u>prior to sending data to the Pilot lab for analysis</u>. It is also required that the k=1 uncertainty of each participant standard is clearly reported at each pressure. Sample data record sheets are provided in Appendix E for recording the calibration data. (Electronic version of the file will be made available).

Proceed as follows for EACH calibration run:

1. Set the null and full-scale of each CDG Signal Conditioner to read $\pm$0000 and 13332, respectively, by turning the Range Select knob to the NULL and F.S. positions and adjusting their small potentiometers. **Do not adjust the SENSOR ZERO potentiometers (covered by tape)**.
2. When adjustments have been completed, return the Range Select switch on each CDG Signal Conditioner to the X1 position. **The X1 position must be used for taking all calibration data. Also confirm that the CDG response is set to "slow".**

3. Check the bubble levels on the baseplate of the PTP and, if necessary, adjust the leveling screws. **Also check the bubble levels whenever it is necessary to make contact with the PTP such as in opening or closing valves V_1, V_2, V_3, or V_5 as well as during the course of the calibration run to ensure that the level position of the transfer standard remains stable to within $\pm$ 1 division.**
4. With valves V_2, V_3 and V_5 open (and valve V_1 closed), record **ten repeat sets of zero-pressure readings** for the transducers in the transfer standard. Follow the instructions in Section 7.2 on the use of the computer/data collection software program. These readings will be used to calculate average zero offsets for the transducers.
5. Close bypass valve V_2 and isolation valve V_5. The transducers RSG1 and RSG2 must be isolated at pressures below 10 Pa to eliminate possible effects of diffusion through elastomer seals in these gauges on the lowest pressure data. Furthermore, their resolution (~30 mPa) limits meaningful readings to pressures 10 Pa and higher.
6. With the pressure standard and interconnecting plumbing evacuated to a pressure ~10^{-3} Pa or lower, open valve V_1 (valve V_3 remains open). Allow sufficient time for the pressure readings of CDG1 and CDG2 to stabilize. Then record **five sets of zero-pressure readings** for the transducers in the transfer standard and for the NMI's pressure standard.

   <u>Optional:</u> If the participant's pressure standard is routinely evacuated between cardinal point pressures, provision is made on the data record sheets to record five repeat zero-pressure readings of the transfer standard and the NMI's pressure standard prior to establishing/generating each cardinal point pressure. This data, if provided, may be used by the pilot laboratory to evaluate zero drift in the transfer standard transducers.
7. Proceed with the calibration. Establish/generate a desired pressure using nitrogen gas and allow sufficient time for the calibration system to equilibrate. At each pressure, record **five repeat** sets of readings (pressure and temperature) of the transfer standard and the associated readings (pressure and temperature) of the NMI's pressure standard. Proceed with the calibration up to 10 Pa.
8. At a pressure of 10 Pa valve RSG1 and RSG2 into the calibration system by **opening isolation valve V_5**, which then remains open for the remainder of the calibration run. Proceed with the calibration up to 100 Pa.
9. Before increasing the pressure above 100 Pa, **close isolation valve V_3** to avoid exposing the 133 Pa CDG's to unnecessary overpressure. **WARNING: Do not expose the transfer standard to (differential) pressures greater than 20,000 Pa at any time to avoid damaging the resonant silicon gauges.**
10. Upon completion of the highest pressure at the end of a calibration run, evacuate the pressure-side of the transfer standard through valve V_1 (remember to **reopen valve V_3 at 100 Pa).** Pump down P_X side of PTP to a stable base pressure ~10^{-3} Pa using an external pump.

<u>**In cases where the NMI's pressure standard is a mercury manometer**</u>:

11. The manometer should be isolated from the calibration system immediately after initial pump down and the system then evacuated (preferably with either a turbomolecular pump or a chilled baffle diffusion pump) **to a pressure ~10^{-3} Pa for a minimum period of 8 hours (overnight) before proceeding to step 12** to reduce mercury vapor remaining in the pressure-side plumbing of the PTP. Mercury vapor will ultimately "poison" the ion

vacuum pump if accumulated in sufficient quantity, so please pump as long as possible before opening V_2.

12. After an overnight pump close valve V_1 and open bypass valve V_2 (valves V_3 and V_5 should already be open, if not repeat step 11).
13. After the system is allowed to stabilize, record **ten zero-pressure readings** for the transfer standard transducers. This data will be used to evaluate the zero stability of the transducers. If another calibration run is planned for this successive day, these initial zero pressure readings can be used for zero evaluation as well as initial zero data recorded in step 4 for the next calibration run.

<u>**In cases where no mercury is present**</u>:

11. After a stable base pressure ~10^{-3} Pa is achieved, close valve V_1 and open bypass valve V_2 (valves V_3 and V_5 should already be open).
12. Record **ten zero-pressure readings** for the transfer standard transducers. This data will be used to evaluate the zero stability of the transducers.

7.4 Stability Check of the Transfer Standard

The gauge pairs of the PTP allow users to monitor the ratios and verify gauge stability. The calibration stability of the transfer standard should be verified by the participating NMI laboratory. The participant is required to perform the stability check after the *final* run to verify gauge stability before shipping to the next lab with the results sent to both the pilot and the next participant. A spreadsheet, shown in Appendix F, will be provided to assist in completion of this analysis. Data on the NMI's pressure standard is <u>not</u> needed to check the transducer stability and is not required at this time.

Additionally, it is recommended (but not required) that each NMI check the stability after the *first* calibration run in order to minimize time wasted if gauges have been compromised during shipping. These results should also be electronically submitted to the pilot.

Gauge stability verification uses readings of the pressure transducers at the following points: 1, 10, 100, 1000, and 7000 Pa, as well as their initial zero-pressure readings. As a measure of stability of each transducer, the spreadsheet will calculate changes in the ratios of pressure readings from nominal values determined by the pilot lab and check to see if they are within tolerance. The following ratios are evaluated for the given pressures:

- RSG1/RSG2 at 7000 Pa (Tolerance: ~0.01%)
- RSG1/RSG2 at 1000 Pa (Tolerance: ~0.01%)
- RSG1/RSG2 at 100 Pa (Tolerance: ~0.1%)
- CDG1/RSG1 at 100 Pa (Tolerance: ~1.0%)
- CDG2/RSG2 at 100 Pa (Tolerance: ~1.0%)
- CDG1/CDG2 at 100 Pa (Tolerance: ~0.1%)
- CDG1/CDG2 at 10 Pa (Tolerance: ~0.5%)
- CDG1/CDG2 at 1 Pa (Tolerance: ~0.85%)

The required data collected during 1st(optional stability check) and 5th runs should be copied and pasted into the provided spreadsheet. The Stability spreadsheet should be emailed to the pilot after values are entered. If the ratios are within the tolerance limits, the spreadsheet will display PTP Stability: “PASS”. If the ratios all pass, the transfer standard can be shipped to the next participant. If any ratio fails, the pilot lab will decide whether the transfer standard may be shipped to the next participating NMI, if additional data needs to be taken, or if the transfer standard should be returned to the pilot laboratory for recalibration.

7.5 Un-installing and Repacking the Transfer Standard

After completing the last calibration run, **evacuate the PTP to a stable pressure ~10^{-3} Pa with valves V_1 V_3, and V_5 open (bypass valve V_2 should still be closed).** If the participant’s pressure standard is a mercury manometer, it should be isolated from the manometer immediately after initial pump down and then the system evacuated using a suitable high vacuum pump (preferably with either a turbomolecular pump or a chilled baffle diffusion pump) **to a pressure ~ 10^{-3} Pa for a minimum period of 8 hours (overnight)**. After evacuating the pressure-side plumbing of the PTP to a stable pressure ~10^{-3} Pa (or overnight), close isolation valve V_1 and then open bypass valve V_2 (isolation valves V_3 and V_5 should be open). **NOTE: Valves V_2, V_3, and V_5 must be in the OPEN position when shipping the transfer standard (under vacuum) to avoid accidental overpressurization of the resonant silicon gauges in the PTP.**

Shut down the computer (Click-on *Start, Shut Down*, and then *Ok*). **Turn off the MiniVac ion pump controller** (see Fig. 3) and then turn off the electrical power to the SEP using the master power switch at the rear of Case 2. Finally, disconnect the signal cables from the instruments in the SEP. **NOTE: Only disconnect the cables connecting the SEP and PTP or other external connections (ie power cable), do not disconnect cables running internal to the SEP.** Carefully wrap the signal cables and place near PTP.

Ensure that V_1 is closed and the PTP is isolated from the pressure standard system. Disconnect the plumbing connections to the participant’s pressure standard. Place a cap on the V_1 VCR fitting and carefully place the bundle of signal cables as compactly as possible at the rear of the PTP. Carefully lift (requires two people) and place the PTP into the bottom section of Case 1 using the handles attached to its aluminum baseplate. **The front (door) of the PTP should be facing the recessed wheels on bottom section of Case 1**. The upper two sections of Case 1 should then be placed over the PTP and all fasteners firmly latched and secured.

Wrap up all remaining cables or external power cables and place into SEP. Close and re-lock pull out monitor and ensure all documentation and keys are placed in drawer in the bottom of Case 2 (SEP). Reposition the front and rear covers of Case 2 and firmly latch all fasteners.

8. REPORTING OF RESULTS

The calibration results required by the pilot laboratory are summarized by the data record sheets given in Appendix E. At the beginning of each run, the Calibration Run Number and date should be clearly labeled. For each set/data point of associated readings of the transfer standard and the participant’s pressure standard the following data is required: {Point Number, CDG1(Pa), CDG2(Pa), RSG1(Pa), RSG2(Pa), P_{REF}(Pa), T_{PRT}(^oC)}, [P_{STD}(Pa), T_{STD}(^oC), U_{STD}(Pa)]

P_{REF} is the reference pressure (vacuum) reading derived from the analog output of the Balzers vacuum gauge controller/display
T_{PRT} is the reading of the thermometer located in the PTP (monitors temperature stability).
P_{STD} is the pressure reading of the participant's pressure standard.
T_{STD} is the temperature reading of the participant's pressure standard.
U_{STD} is the uncertainty of the participant's pressure standard (k=1) in Pa.

Values for Pt. No., CDG1, CDG2, RSG1, RSG2, P_{REF}, and T_{PRT} are recorded by the "CCM 2012" program. P_{STD}, T_{STD}, and U_{STD} are recorded by each NMI must either be recorded manually (by paper or typing into program when prompted), sent to the program by RS232, or recorded separately.

Each data run should consist of:

- Ten repeat readings of the transfer standard at zero pressure (isolation valve V_1 closed; bypass valve V_2 and isolation valves V_3 and V_5 open).
- Five repeat readings of the transfer standard and the participant's standard at zero pressure (bypass valve V_2 and isolation valve V_5 closed; isolation valves V_1 and V_3 open).
- Five repeat readings of the transfer standard and the pressure standard at each cardinal point pressure (see section 7.3).
- Optional After each cardinal point pressure, five repeat zero pressure readings of the transfer standard and the pressure standard (used to zero check CDGs for static expansion systems).
- Ten repeat readings of the transfer standard after returning to zero pressure at the end of the calibration run (isolation valve V_1 closed; bypass valve V_2 and isolation valves V_3 and V_5 open). Mercury manometers are exempt (see Section 7.3), but will be required to take a final set of ten zero points after an overnight pump out on the final run.

The data will be collected from each NMI and evaluated at each of the mandatory pressures. For pressures above 100 Pa, the RSGs will be used. At the 100 Pa pressure, the CDGs stability will be corrected using the RSGs and the corrected CDGs will be used from 100 Pa to 1 Pa. At each pressure, the gauges will be linearly corrected using the ratio of gauge reading to standard to determine the exact gauge reading at the target pressures. Gauge pairs are then averaged together for each of the five runs to determine the transfer standard pressure for each cardinal pressure. Results from all NMIs participating at each pressure point will be used to determine the reference value used for the final comparison.

In addition to the data sheets for each run, participants should complete the "Description of Standard" form included in Appendix G. All datasheets should be sent by email as a Microsoft Excel files (if possible) to jayh@nist.gov or recorded on a CDR which is then forwarded by express mail to Jay Hendricks, 100 Bureau Drive Stop 8364, Gaithersburg, MD 20899-8364 USA. *Data should be sent within 8 weeks of shipment of the package to the subsequent NMI*. If this is not possible or the data cannot be sent then please contact the pilot lab for instructions.

APPENDIX A: Description of Instruments in the Transfer Standard

Transfer Standard Package A

Transducer Identifier	Manufacturer	Transducer Model	Range (Pa)	Transducer S/N	Signal Conditioner Model	Signal Conditioner S/N	Power Consumption (W)
CDG1 (Middle)	MKS Instruments	698AD	133	92163306A	270D-4	94162203A	21
CDG2 (Bottom) 532439	MKS Instruments	398HD	133	44749-2	270B-4	53467-2-3	21
RSG1 (Door) 629595	Yokogawa	265381-S11	10,000	91G100587	--	--	<1
RSG2 (Back) 635302	Yokogawa	265381-S11	10,000	91HC00046	--	--	<1
Computer 634775							

Ion Vacuum Pump/Controller:
Varian 8 l/s VacIon pump Model 911-5005 with magnet Model 911-0030
Varian MiniVac controller Model 9290190
Power consumption 21 W

Reference Vacuum Gauge/Controller:
Balzers Compact Full Range Gauge Model PKR 250 Range $5x10^{-7}$ … $1x10^{5}$ Pa
Balzers Single Gauge Control Unit Model TPG 251
Power consumption 14 W

Transfer Standard Package B

Transducer Identifier	Manufacturer	Transducer Model	Range (Pa)	Transducer S/N	Signal Conditioner Model	Signal Conditioner S/N	Power Consumption (W)
CDG1 (Middle)	MKS Instruments	398HD	133	92055308A	270D-4	96088219A	21
CDG2 (Bottom)	MKS Instruments	398HD	133	91354310A	270D-4	217902	21
RSG1 (Door) 635300	Yokogawa	265381-S11	10,000	91HC00044	--	--	<1
RSG2 (Back) 635301	Yokogawa	265381-S11	10,000	91HC00045	--	--	<1
Computer 634776	--	--	--	--	--	--	<200

Ion Vacuum Pump/Controller:
Varian 8 l/s VacIon pump Model 911-5005 with magnet Model 911-0030
Varian MiniVac controller Model 9290190
Power consumption 21 W

Reference Vacuum Gauge/Controller:
Balzers Compact Full Range Gauge Model PKR 250 Range $5x10^{-7}$ … $1x10^{5}$ Pa
Balzers Single Gauge Control Unit Model TPG 251
Power consumption 14 W

APPENDIX B: Arrival/Departure Check Report

(electronic file to be provided)

Arrival Check List

1) Arrival Date: ______________________________

2) Did both the SEP and PTP arrive? YES / NO

3) Inspect package, is there any damage? YES / NO

If YES, Please describe damage:

____

____

____

____

4) Have you moved the package into the Lab? YES / NO

If NO, what date do you expect them to be in place?

____

(NOTE: a 24hr stabilization is recommended if exterior temperatures are different than Lab temperature by more than 5°C)

5) Have you removed the foam shipping wedges from above the CDGs in the PTP? YES / NO

(NOTE: Before plugging in the system, ensure that you are using 110V, 50 or 60Hz ONLY!)

6) Have you powered on the package? YES / NO (please refer to Protocol document for instructions)

If YES, please note the P_{REF} (Balzers gauge) pressure before turning on the Ion Pump or opening V_1?

_______________________________________ (i.e. 1.8e2 Pa)

Email this form to jayh@nist.gov within one week of arrival and CC the NMI who shipped the package.

Departure Check List

1) Shipping Date: ______________________________

2) Shipping Method: ______________________________ (air freight recommended)

3) Please verify the following:

Keys in drawer of SEP:	YES / NO
Manuals in drawer of SEP:	YES / NO
PTP at Vacuum:	YES / NO
V1, V4 closed:	YES / NO
V2, V3, V5 Open:	YES / NO
CDG Foam Shipping wedges in place:	YES / NO
Data removed from SEP computer:	YES / NO
Data backed-up/archived at NMI:	YES / NO
Cables wraped and in place:	YES / NO
Shipping cases locked/closed:	YES / NO
ATA-Carnet or Destination Letter in place:	YES / NO

Email this form to jayh@nist.gov before departure and CC the NMI that will receive the package

APPENDIX C: Gauge Averaging Methodology

Do not adjust the gauge averaging. The following information is for explanatory purposes only.

The RSGs are set to 4.0 s averaging/windowing in hardware that remains set even when the power is off. Under no circumstances should this setting be changed as it is not reset by the running the CCM computer program. Additionally, under no circumstances shall the RSG RS232 ports be connected to other computer systems and or hardware other than that which is supplied. The CDGs are set to 400 ms (slow response on front panel) and read with 34970A HP voltmeter. The 34970A HP is set to auto-zero, internal averaging power line cycles (PLC) is set to 100.

For synchronizing readings, the 34970A takes 17ms per reading * 100 PLC or a total of 1.7 seconds. Additionally, there is a 1.7 second auto zero procedure resulting in 3.4 seconds per reading. Minor data transmission overhead results in ~3.6 seconds for one CDG reading.

Between CDG readings, every 3.6 seconds, RSG A and B are both read capturing the previous 4 seconds because RSGs are set to 4 second averaging. This means that the data read for the RSGs is taken in parallel (at the same time) as the CDGs. The program is set to read CDG 1, followed by a query of RSG 1 and RSG 2, and then CDG 2, followed by a second query of RSG 1 and RSG 2 for a total time of 7.2 seconds.
A complete measurement data point is determined by:

- CDGA first reading, then RSGA & RSGB simultaneous read number 1.
- CDGB first reading, then RSGA & RSGB simultaneous read number 2.
- CDGA second reading, then RSGA & RSGB simultaneous read number 3.
- CDGB second reading, then RSGA & RSGB simultaneous read number 4.
- CDGA third reading, then RSGA & RSGB simultaneous read number 5.
- CDGB third reading, then RSGA & RSGB simultaneous read number 6.

This procedure takes approximately 24 seconds, with around 22 seconds of data collected by both RSGs. For CDGs approximately 10.8 seconds is devoted to CDGA and 10.8 seconds is for CDGB. Because the voltmeter is set to auto zero, ½ of CDG time goes to checking the voltmeter zero, resulting in approximately 5.4 seconds of data collected on each CDG. Each CDG is read at the beginning, middle and end of the 22 seconds window.

All the readings taken are averaged into the recorded value using the following:
CDG 1= CDG 1 readings (1,2,3)/3
CDG 2= CDG 2 readings (1,2,3)/3
RSG 1= RSG 1 readings (1,2,3,4,5,6)/6
RSG 2= RSG 2 readings (1,2,3,4,5,6)/6

APPENDIX D: Data transfer over the RS232 Bus

To record data via RS232, connect a twisted (included in TSP Drawer) RS232 cable from com#4 on the transfer standard package (A or B) to any com port on NMI's pressure standard computer.

Use the following commands to send pressure and temperature data to the transfer standard computer:

Optional clear command: "$$$"
Optional hold command: "***"
Pressure Command: "@####.#####T##.####~" where # indicates a number of arbitrary length and number of decimal places. For example Send "*@123.456*T*23.00~*" where a pressure of 123.456 Pa and temperature of 23.00 ^{o}C was sent. Any double precision number can be sent and stored in the transfer standard package.

Example:

> NMI Standard getting ready to take pressure
> Send clear command: "$$$" (if using clear command, must be at least 24s before issuing hold or pressure reading)
> Standard taking pressure
> Standard completes raw measurement readings
> Send hold command: "***"
> NMI Standard calculates pressure (TSP holds current values for up to 60s)
> Send pressure value: "@123.45678@23.4567~"

For Visual Basic:

```
MSCommPort.PortOpen = True
MSCommPort.Output = Chr(36) & Chr(36) & Chr(36)  '$$$
Wait(25)  'Wait > 24s for TSP to take data
MSCommPort.Output = Chr(42) & Chr(42) & Chr(42)  '***
Wait(10)  'Wait MAX 60s
MSCommPort.Output = Chr(64) & Pressure & "T" & Temperature & Chr(126)  'Where Pressure and Temperature are the NMI's measured values
MSCommPort.PortOpen = False
```

APPENDIX E: Data Record Sheets

(electronic file to be provided)

		Transfer Standard						Pressure Standard		
Nominal Pressure (Pa)	**Point Number**	**CDG1 (Pa)**	**CDG2 (Pa)**	**RSG1 (Pa)**	**RSG2 (Pa)**	**P_{REF} (Pa)**	**T_{PRT} (°C)**	**P_{STD} (Pa)**	**T_{STD} (°C)**	**U_{STD} (k=1) (Pa)**
V_1 closed V_2, V_3 and V_5 open 0 Pa	1							Not required		
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	10									
Close V_2 & V_5 0 Pa	1									
	2									
	3									
	4									
	5									
1 Pa	1									
	2									
	3									
	4									
	5									

Nominal Pressure (Pa)	Point Number	Transfer Standard CDG1 (Pa)	CDG2 (Pa)	RSG1 (Pa)	RSG2 (Pa)	P_{REF} (Pa)	T_{PRT} (°C)	Pressure Standard P_{STD} (Pa)	T_{STD} (°C)	U_{STD} (k=1) (Pa)
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
3 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
7 Pa (Optional)	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									

		Transfer Standard						Pressure Standard		
Nominal Pressure (Pa)	**Point Number**	**CDG1 (Pa)**	**CDG2 (Pa)**	**RSG1 (Pa)**	**RSG2 (Pa)**	**P_{REF} (Pa)**	**T_{PRT} (°C)**	**P_{STD} (Pa)**	**T_{STD} (°C)**	**U_{STD} (k=1) (Pa)**
Open V_5 10 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
30 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
70 Pa (Optional)	1									
	2									
	3									
	4									
	5									

		Transfer Standard						Pressure Standard		
Nominal Pressure (Pa)	**Point Number**	**CDG1 (Pa)**	**CDG2 (Pa)**	**RSG1 (Pa)**	**RSG2 (Pa)**	**P_{REF} (Pa)**	**T_{PRT} (^oC)**	**P_{STD} (Pa)**	**T_{STD} (^oC)**	**U_{STD} (k=1) (Pa)**
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
100 Pa After recording Data, **Close V_3**	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
300 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									

		Transfer Standard						Pressure Standard		
Nominal Pressure (Pa)	**Point Number**	**CDG1 (Pa)**	**CDG2 (Pa)**	**RSG1 (Pa)**	**RSG2 (Pa)**	**P_{REF} (Pa)**	**T_{PRT} (°C)**	**P_{STD} (Pa)**	**T_{STD} (°C)**	**U_{STD} (k=1) (Pa)**
700 Pa (Optional)	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
1000 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
3000 Pa	1									
	2									
	3									
	4									
	5									

		Transfer Standard						Pressure Standard		
Nominal Pressure (Pa)	**Point Number**	**CDG1 (Pa)**	**CDG2 (Pa)**	**RSG1 (Pa)**	**RSG2 (Pa)**	**P_{REF} (Pa)**	**T_{PRT} (^oC)**	**P_{STD} (Pa)**	**T_{STD} (^oC)**	**U_{STD} (k=1) (Pa)**
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
7000 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									
10,000 Pa	1									
	2									
	3									
	4									
	5									
0 Pa (Optional)	1									
	2									
	3									
	4									
	5									

		Transfer Standard						Pressure Standard		
Nominal Pressure (Pa)	**Point Number**	**CDG1 (Pa)**	**CDG2 (Pa)**	**RSG1 (Pa)**	**RSG2 (Pa)**	**P_{REF} (Pa)**	**T_{PRT} (^{o}C)**	**P_{STD} (Pa)**	**T_{STD} (^{o}C)**	**U_{STD} (k=1) (Pa)**
Close V_1 Open V_2, V_3, and V_5 0 Pa (For mercury manometers see note following step 11,Sec.7.3)	1							Not required		
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	10									

APPENDIX F: PTP Stability Spreadsheet

(Example only; electronic excel file will be provided to participant; pasting values into sheet and calculations will be automatic)

Gauge Initial Zero-Pressure Readings

Date	Point	Time	CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg	Pref	Tprt
	1		0	0	0	0		
	2		0	0	0	0		
	3		0	0	0	0		
	4		0	0	0	0		
	5		0	0	0	0		
	6		0	0	0	0		
	7		0	0	0	0		
	8		0	0	0	0		
	9		0	0	0	0		
	10		0	0	0	0		

PTP STABILITY: PASS

Average Zero-Pressure Readings

CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg
0	0	0	0

CDG Stability Correction Factor

RSG1/CDG1	RSG2/CDG2
0.98328417	0.98328417

1 Pa Pressure Readings

Date	Point	Time	CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg	Pref	Tprt
	1		1	1	1	1		
	2		1	1	1	1		
	3		1	1	1	1		
	4		1	1	1	1		
	5		1	1	1	1		

GAUGE STABILITY RESULTS

CDG1/CDG2	RSG1/CDG1	RSG2/CDG2	RSG1/RSG2
PASS			
PASS			
PASS			
PASS			
PASS			

10 Pa Pressure Readings

Date	Point	Time	CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg	Pref	Tprt
	1		10	10	1	1		
	2		10	10	1	1		
	3		10	10	1	1		
	4		10	10	1	1		
	5		10	10	1	1		

GAUGE STABILITY RESULTS

CDG1/CDG2	RSG1/CDG1	RSG2/CDG2	RSG1/RSG2
PASS			
PASS			
PASS			
PASS			
PASS			

100 Pa Pressure Readings

Date	Point	Time	CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg	Pref	Tprt
	1		101.7	101.7	100	100		
	2		101.7	101.7	100	100		
	3		101.7	101.7	100	100		
	4		101.7	101.7	100	100		
	5		101.7	101.7	100	100		

GAUGE STABILITY RESULTS

CDG1/CDG2	RSG1/CDG1	RSG2/CDG2	RSG1/RSG2
PASS	PASS	PASS	PASS
PASS	PASS	PASS	PASS
PASS	PASS	PASS	PASS
PASS	PASS	PASS	PASS
PASS	PASS	PASS	PASS

1000 Pa Pressure Readings

Date	Point	Time	CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg	Pref	Tprt
	1		1000	1000	1000	1000		
	2		1000	1000	1000	1000		
	3		1000	1000	1000	1000		
	4		1000	1000	1000	1000		
	5		1000	1000	1000	1000		

GAUGE STABILITY RESULTS

CDG1/CDG2	RSG1/CDG1	RSG2/CDG2	RSG1/RSG2
			PASS
			PASS
			PASS
			PASS
			PASS

7000 Pa Pressure Readings

Date	Point	Time	CDG 1 avg	CDG 2 avg	RSG 1 avg	RSG 2 avg	Pref	Tprt
	1		7000	7000	7000	7000		
	2		7000	7000	7000	7000		
	3		7000	7000	7000	7000		
	4		7000	7000	7000	7000		
	5		7000	7000	7000	7000		

GAUGE STABILITY RESULTS

CDG1/CDG2	RSG1/CDG1	RSG2/CDG2	RSG1/RSG2
			PASS
			PASS
			PASS
			PASS
			PASS

APPENDIX G: NMI Description of Standard(s)

NMI Name:	

Description of Standards: (Provide a brief description of each standard used, applicable range, and published uncertainty)	(1) Description: Range: Uncertainty (k=2): (2) Description: Range: Uncertainty (k=2): (3) Description: Range: Uncertainty (k=2): (4) Description: Range: Uncertainty (k=2):

	Select Standard to be used (1)	(2)	(3)	(4)
1 Pa	( )	( )	( )	( )
3 Pa	( )	( )	( )	( )
7 Pa	( )	( )	( )	( )
10 Pa	( )	( )	( )	( )
30 Pa	( )	( )	( )	( )
70 Pa	( )	( )	( )	( )
100 Pa	( )	( )	( )	( )
300 Pa	( )	( )	( )	( )
700 Pa	( )	( )	( )	( )
1000 Pa	( )	( )	( )	( )
3000 Pa	( )	( )	( )	( )
7000 Pa	( )	( )	( )	( )
10000 Pa	( )	( )	( )	( )

	Select Measurement Method Manometer	SES	FPG	PG	Other
Standard (1)	( )	( )	( )	( )	( )
Standard (2)	( )	( )	( )	( )	( )
Standard (3)	( )	( )	( )	( )	( )
Standard (4)	( )	( )	( )	( )	( )