Sierra Series 101 Cal-Bench™

Automated Primary Calibration System

Instruction Manual

Part Number IM-101
09/99 Revision F

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Revision E: updated all chapters with new sonar board data.
Revision F: updated Chapter 4 sonar alignment procedure.

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Chapter 1 The Cal-Bench System

Introduction

The Sierra Instruments Cal-Bench™ system is a fully automated, computer-controlled primary gas flow calibration system. The Cal-Bench system calibrates any type of mass flow meter, mass flow controller, rotameter or other gas flow monitoring device. The system accommodates all inert gases and has a range of 1 to 50,000 SCCM. Calibrations performed with the Cal-Bench system are based on the US. National Institute of Standards and Technology (NIST) primary measurements of length and time.

Using This Manual

This manual provides the information you need to install and operate the Cal-Bench system. The five chapters of this manual cover these areas:

- Chapter 1 covers system components and specifications
- Chapter 2 provides information needed for installation
- Chapter 3 covers all aspects of system software and operation
- Chapter 4 covers maintenance and calibration procedures
- Chapter 5 outlines troubleshooting procedures

Additional data in the Appendices include supplementary software data, certification certificates, and control box information. For optimal system performance, make sure to read and follow the certification and maintenance schedules outlined in Chapter 4.

Notes, Cautions and Warnings

We use note, caution and warning symbols throughout this book to draw your attention to important information.

Note

A note symbol appears with a short message in italic type to alert you to an important detail.

Caution

A caution symbol appears with information in bold type that is important for protecting your equipment and performance. Be careful to read and follow all cautions that apply to your application.

Warning

A warning symbol appears with information in bold type that is important for protecting against personal injury and/or equipment damage. Pay very close attention to all warnings that apply to your application.

Technical Assistance

If you encounter a problem with your Cal-Bench™ system, review the configuration information for each step of the start up and operation procedures. Verify that your settings and adjustments are consistent with factory recommendations. Refer to Chapter 5, Troubleshooting, for specific information and recommendations.

If the problem persists after following the troubleshooting procedures outlined in Chapter 5, contact Sierra Instruments, Technical Support at (800) 866-0200 or (831) 373-0200 between 8:00 a.m. and 5:00 p.m. PST. When calling technical support, have the following information on hand: the system serial number, your Instruction Manual, flow range of the unit under test and the problem you are encountering.

How the Cal-Bench System Operates

In operation, the calibration gas flows through the device under test and into one of the three tubes in the Cal-Bench™ system The tubes are precision bore quartz borosilicate glass, each equipped with a frictionless mercury sealed piston. The tubes are sized to provide a ten to one ratio in volumetric displacement between the tubes.

As the gas enters the tube, the sealed piston rises. The Cal-Bench system uses a non-intrusive, non-contact technique for measuring the position of the piston in the tube. A specialized sonar transceiver emits a pulse of sound energy operating at approximately 50 kHz. This pulse of energy travels down the tube, is reflected from the top of the piston and returns to the transceiver. The system measures the transit time of the energy pulse, the transit time becoming shorter as the piston rises. The computer calculates the speed of sound based on the ambient conditions of temperature, pressure and relative humidity. By knowing the speed of sound, and the transit time of the sonar pulse, the position of the piston can be determined with a resolution of 0.006 inches.

To determine the mass flow rate, the Cal-Bench system uses the ambient conditions and converts actual volume displacement into mass flow. The data on flow rate is displayed on the computer terminal while the test is underway, permitting fast, real time calibration.

The Bell Prover option extends the calibration range of the standard Cal-Bench system. The Bell Prover is essentially a larger “glass tube” with the ability to measure higher flows. The prover is constructed of 300 Series stainless steel, fitted with inlet and outlet valving, two counter weights, an optical encoder, and automated inputs of temperature and back pressure measurements.

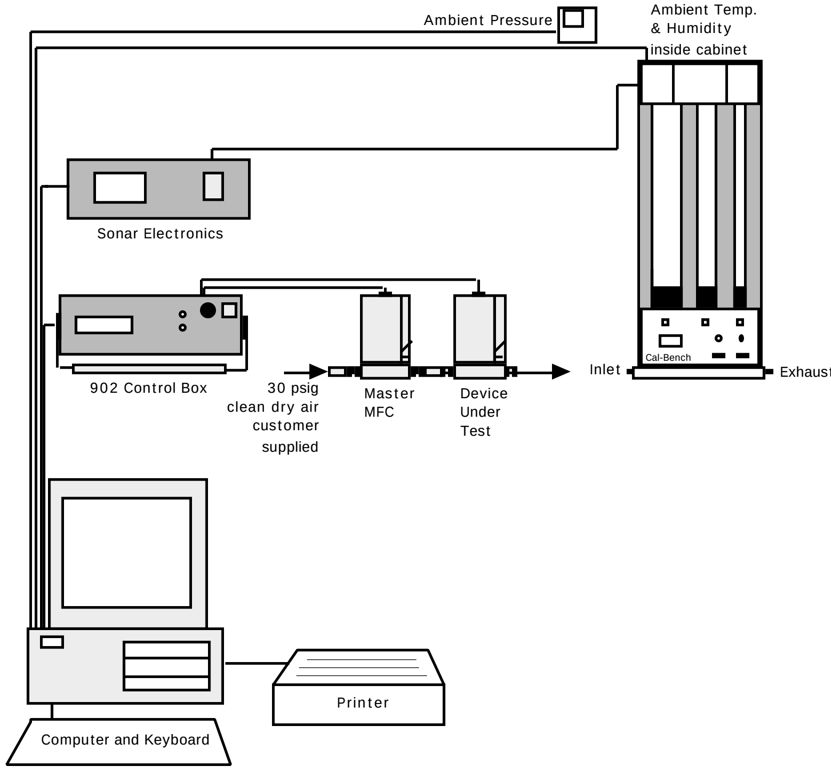


Figure 1-1. Cal-Bench System Components

System Components

The Cal-Bench™ main test stand is completely self-contained and includes all the necessary piping, valves, instrumentation and controls to operate the calibration system. Each glass tube is supported by the base plate and sealed with mercury. A sonar transceiver is located in the top of each tube. The entire upper section of the Cal-Bench system is sealed and vented through mercury filters to prevent mercury vapors from entering the work space.

The front panel of the calibration test stand includes a thermometer displaying the temperature of the gas flowing into the Cal-Bench system. A manual vent switch, an automatic safety vent indicator, a reset switch and an active tube indicator are also incorporated into the test stand front panel.

The Cal-Bench system includes:

- Calibration stand and console with three transceivers and three flow tubes
- Sonar electronics
- PC-compatible computer (CPU)
- Video monitor
- Keyboard
- System software
- Power cords and interconnecting cables

Generate Mode option sub-system components include:

- Generate mode electronics (902 Control Box Assembly) with a separate readout/power supply for the control valves and device under test
- 3 control valves with standard ranges of 0-200, 0-2000, and 0-50,000 SCCM
- Optional printer with cable

Bell Prover option sub-system components include:

- 5 or 20 cubic foot 300 Series stainless steel bell prover
- Linear encoder
- Automated inputs of temperature and pressure
- Interconnecting cables

System Software Features

The Cal-Bench system software offers you the following modes of operation:

Calibrate Mode calibrates any single gas or mixture of gases, permits easy selection of the gas mixture, automatically calculates the correct K-factor, and indicates the recommended calibration gases.

Generate Mode automatically generates the desired flow, utilizing the control valve in a feedback control loop, and allows for selection of up to 32 calibration points.

Final QC Calibration Mode automatically calibrates or tests and validates mass flow controllers, mass flow meters and rotameters and records test data.

Time Response Mode displays and prints out the time response curve of the test specimen.

Leak Test Mode quickly verifies the leak integrity of the system.

Records Mode recalls all calibration data on each device, in an easily accessed database.

Verify Sonar Mode allow you to compare the sonar measurements with any standard device, typically a cathetometer and/or laser interferometer.

Manual Transfer Standard Mode allow calibration using transfer standards.

D/A and A/D Adjust Mode allows in situ validation/calibration of digital to analog and analog to digital converts.

System Information Mode allows for easy system validation.

Specifications

Cal-Bench System

Operating Conditions

Temperature: 64 – 74 °F (18 – 23°C)
Barometric Pressure: 500 to 825 mm of Hg
Relative Humidity:20% to 80 % non condensing

Accuracy

Better than 0.2% of indicated flow rate.

Range

Small Tube	1 SCCM to 1.0 SLM
Medium Tube	1.0 SLM to 10 SLM
Large Tube	10 SLM to 50 SLM

Volume Resolution

Small Tube	0.019 cubic centimeters
Medium Tube	0.236 cubic centimeters
Large Tube	2.472 cubic centimeters

Time Resolution

1 microsecond

Safety Features

Mercury filters, automatic overfill bypass, automatic bypass in event of power failure, automatic bypass on excess back pressure, safety shield

Data Entry

Via PC-compatible computer

Power Requirements

115± 10% VAC standard, 230 VAC ± 10% optional

Dimension and Weight

Calibration Stand: 15"W x 17"D x 46"H
Computer/display/electronics: 17"W x 19"D x 20"H
System components, 200 pounds

Gas Hardware

Valves, tubing, and facility connections are provided by the customer.

Generate Mode Electronics Option

General

The 902 Control Box Assembly powers/reads up to two transducers. Flow and Setpoint are directly displayed in 0 to 100 percent. Outputs are 0-5 volts for each channel. Valve control functions of Close/Purge/Monitor. The unit has built-in 10 turn precision setpoint potentiometers. Auto/Manual switches on the front panel allow setpoint selection for mass flow controllers.

Input Power

115 VDC @ 1.25 A

Output Power

+15 VDC @ 1.25 A
-15 VDC @ .90 A

Output Hum and Noise

Less than .05 volts RMS

Display

3-1/2 digit LCD in 0 to 100% analog

Controls

Power ON/OFF. Two Channel Select (two channel configurations). Two precision 10 turn setpoint pots as required for controllers only.

Inputs

0-5 VDC for each channel
0-5 VDC is referred to common

Bell Prover Option

General

The unit is available in two sizes, the MBP 5, with an internal volume of 5 cubic feet and the MBP 20 with an internal volume of 20 cubic feet.

Accuracy

0.5% of reading

Flow Ranges

MBP 5: 1 to 20 CFM
MBP 20: 2 to 80 CFM

Power Requirements

115± 10% VAC standard, 230 ± 10% VAC optional
350 watts maximum

Dimensions and Weight

MBP5:	Height 88.4”
	Bell diameter 24”
MBP20:	Height 108.8”
	Bell diameter 36”

MBP5:	200 pounds
MBP20:	500 pounds

Gas Hardware

Valves, tubing, and facility connections are provided by the customer.

Chapter 2 Installation

The Cal-Bench™ system installation is simple and straightforward. Covered in this chapter are these procedures:

- Facility Requirements
- Receiving Cal-Bench System Components
- Installing System Components

Facility Requirements

Workspace Required the Cal-Bench System

- Work table, 3 feet by 6 feet, for the Cal-Bench system components including the CPU, monitor, keyboard, sonar electronics, 902 Control Box Assembly and optional printer.

- Small stand 15” x 24” x 18” for the cabinet holding the calibration tubes. Five feet of headroom is required above this cabinet to allow for installation of calibration tubes.

Power

- 110 VAC (optional 220 VAC)
- High quality surge protector power strip with six outlets.

Plumbing

- Gas that is clean, dry, oil- and particulate-free, preferably air or nitrogen. (30 psig maximum, dependent on individual mass flow controller rating.)

- If your facility has compressed air, make sure the air coming from the compressor passes through an oil coalescing filter, air drier, water trap and a 0.5 micron particulate filter.

- Tubing, 1/4” or 1/2” to reach the Cal-Bench system work space from the gas supply. The tubing must be capable of handling the line pressure of your gas supply. Two high pressure regulators located at the Cal-Bench work area.

You will need to determine what type and quantity of fittings are needed to plumb the gas lines, regulator, valves, filter, controllers and devices undergoing test. See the figures on the following pages for examples of Cal-Bench system plumbing.

Mercury

Due to shipping constraints, we are not able to supply mercury. You will need approximately two pounds of triple distilled mercury for the Cal-Bench system. Contact Sierra Instruments, Customer Service Department at (800) 866-0200 for assistance in purchasing mercury.

Workspace Required for the Bell Prover Option

The bell prover must be positioned within 15 feet of the Cal-Bench system computer. We recommend access of 360° around the bell prover. Floor space required is 6 to 8 feet depending on the bell prover size. The area must be large enough to accommodate the Cal-Bench system, the bell itself and room enough to plumb the air lines from the air supply and the Device Under Test.

Bell Prover Plumbing

Additional hardware and materials will be required to install the optional bell prover. You will need to determine the type and quantity of fittings needed to plumb the gas lines, regulators, valves, filters, controllers and the DUT into the system.

A source of compressed, clean, dry, oil- and particulate-free air is required. The air supply must be capable of supplying 120 CFM for the 20 cubic foot bell prover and 30 CFM for the 5 foot bell prover. The air supply should be able to supply the pressure required by the Device Under Test (DUT).

To ensure clean dry air, we recommend plumbing an oil coalescing filter, air drier and water trap in series after the output of the compressor. Two single stage or one dual stage pressure regulator(s) are required to minimize hysteresis in the air supply. These pressure regulators should be 1.25” Female NPT for mounting with gauges capable of reading to 100 PSI or twice the operating pressure.

Bell Prover Oil

The bell prover should be filled with a non-corrosive, high oxidation stable, low vapor pressure oil. Do not use water due to its high vapor pressure and corrosive nature. We recommend Shell’s Diala® AX. The 20 cubic foot bell prover requires 38 gallons of oil. The 5 cubic foot bell prover requires 19 gallons of oil.

Receiving System Components

The Cal-Bench™ is completely assembled and tested at Sierra Instrument's facility prior to shipment. The system is shipped complete, with the exception of the mercury.

The system consists of the following major items. For your convenience, use the complete check-off list in Appendix B to verify receipt of all Cal-Bench system components.

- Cal-Bench calibration stand assembly
- Large tube
- Medium tube
- Small tube
- Large piston with target
- Medium piston with target
- Small piston with target
- PC-compatible computer (CPU)
- Monitor
- Keyboard
- Sonar Transceivers (3)
- Plexiglas shield
- Generate Mode electronics (902 Control Box Assembly, optional)
- Sonar Electronics
- Generate hardware (mass flow control valves, optional)
- Barometer (temperature and humidity sensors included in calibration stand)
- Power cords and computer cables
- Printer (optional)
- Bell prover (optional)

Carefully open and unpack each packing carton. Use the Cal-Bench Item List in Appendix B to verify that all equipment has been received and is in good condition. Take special care when inspecting the cartons containing the glass tubes and in removing and handling the tubes.

If any questions arise in the unpacking or installation of the Cal-Bench system, contact the factory.

Installation of the Cal-Bench System

Calibration Stand Assembly

The site for installing the Cal-Bench™ system should be carefully chosen. Once assembled, the system should not be moved due to the risk of mercury spillage. Allow sufficient overhead room for installation of tubes and pistons, and for cleaning the tubes. If overhead room is not available, install the glass tubes at floor level and then carefully place the Cal-Bench in its permanent location. (This will require two people). See the following figures for examples of Cal-Bench system installation and plumbing diagrams.

The Cal-Bench system is equipped with a mercury filter system to eliminate the hazard of continuous exposure to mercury vapors. Seals are installed at the time the precision-bored glass tubes are set into place in the console. Seals are composed of an O-ring and a threaded ring that fits over the end of the glass tubes.

Installation Procedure

Because most Cal-Bench systems are installed by a factory representative, the following instructions are general in nature. Before assembling any components, read and understand the procedures in Chapter 4 of this manual. For a complete list of tools and materials required, see the tube cleaning procedure on page 4-2.

1. Clean tubes with ammonia free glass cleaner and dry the insides thoroughly before installing in the cabinet. Do not clean with alcohol or other substances. (See tube cleaning procedure in Chapter 4 for instructions.) We use and recommend Ammonia-Free Windex.®

2. With the console standing upright, loosen and remove the screws on the hood of the console and flip it back to expose the transducers and the top plate that holds the tubes in place.

3. Remove the brackets that hold the transducers in place and move transducers out of the way. One person may slide a glass tube into the appropriate sized hole from the top while another person positions the bottom of the tube.

Caution

Do not attempt to insert tubes from the front of the console. If the tube is not properly aligned within the hole, it will not slide easily into position and any forceful movement will break or damage it.

1. Before setting the tube on the bottom base plate, lightly lubricate the O-ring and slip it over the bottom of the tube, followed by the threaded ring. Carefully work the O-ring and threaded ring to the top of the tube and screw the threaded ring in several turns. Leave the threaded ring loose so the tube may be easily raised to install the mercury seal in bottom block.

2. Read the Material Safety Data Sheet that is supplied with your mercury (and also included in Appendix B of this manual).

Warning

Mercury and Mercury Vapors are toxic! The utmost precaution and care must be taken while transporting and handling mercury. Failure to take appropriate measures when handling mercury could result in hazardous exposure of personnel.

Warning

When a syringe is loaded with mercury, NEVER point the needle downward when away from a confined tray. Mercury will fall out of the syringe onto the floor contaminating your work area.

1. When the three tubes are in place along with their O-rings and the threaded rings are loosely screwed in, carefully inject approximately ⅛ inch of mercury into the wells of the bottom plate. Do not overfill the mercury wells.

2. Gently set each tube into its well in the bottom plate. Make sure that the mercury makes a complete seal between glass and bottom plate. Also ensure that the mercury makes complete contact with the ground wire. (Dirty mercury is acceptable as a seal in the wells.)

3. Install the pistons with gas turned off. Use Calibrate to select the tube for installing the piston. Use dust free gloves while handling the piston. Without allowing the piston to fall to the bottom of the tube, hold the piston so the groove cut out for the mercury seal is just below the top of the tube. With a syringe, inject a small amount of mercury into the center hole at the top of the piston until a complete mercury seal is created between piston and the inner wall of the glass tube.

4. Place the target on top of the piston and release it. The piston should fall smoothly to the bottom of the tube. If the piston does not fall smoothly, the tube may need to be cleaned and/or dried. See tube cleaning procedure in Chapter 4.

5. Replace transducers and their hold-down brackets. It is important that the transducers align properly in the top plate for the sonar signal to bounce off the target and be read by the transducer. Install the small tube bevel extension before the transducer is placed on top of the tube. The sloped portion of the bevel extension must point upward. For safety of the small tube, be very careful when placing or removing this transducer.

6. Clean up any spilled mercury. Small bits of mercury may need to be vacuumed. Tighten the threaded rings to keep the tubes from moving.

Caution

To allow for future tube removal, do not over-tighten the threaded ring.

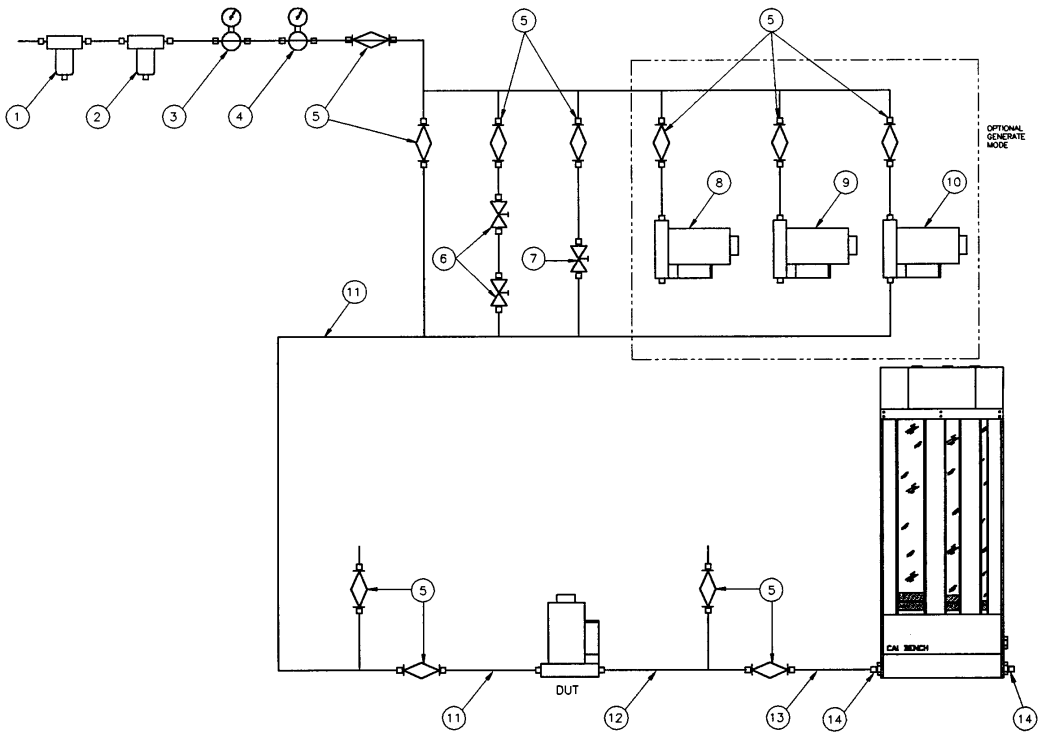
1. Flip the hood back on top of the console. Adjust cables so they do not crimp or bind on the mercury filters or sonar transducers. Screw down the hood so that a good seal is formed all the way around the top.

2. Install the Plexiglas® window by inserting the top first. Lift the window up via the metal tabs on the face of the window. Insert bottom and let the window down to rest on the bottom base plate.

3. Sonar alignment is required anytime the small tube is removed from the cabinet. Follow the sonar alignment procedure in Chapter 4.

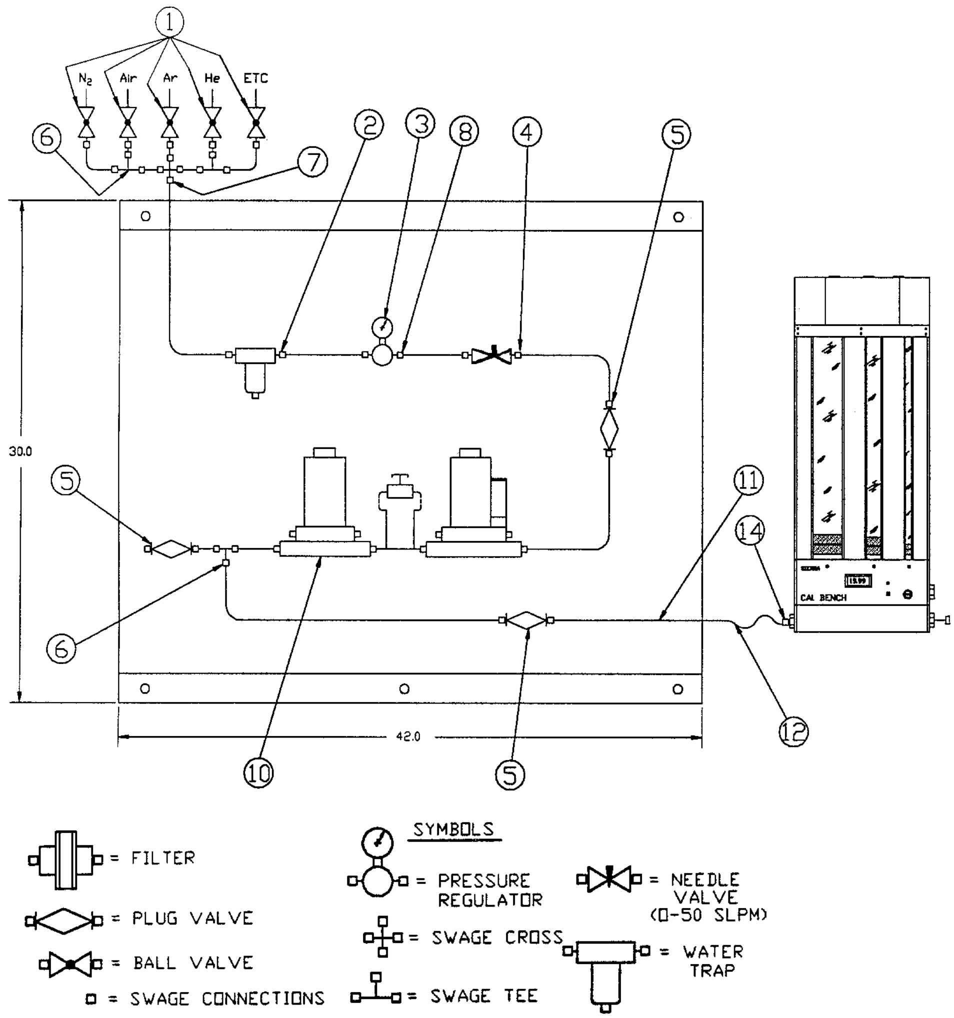
This completes the setup of the Cal-Bench™ system cabinet.

Use the following figures as a reference to locate and connect the remaining Cal-Bench system components. Avoid excessive cable lengths between system components.



Item	Description	Item	Description
1	Oil trap	8	0-50,000 sccm master MFC
2	Water trap	9	0-2,000 sccm master MFC
3	0-160 psi pressure regulator	10	0-200 sccm master MFC
4	0-60 psi pressure regulator	11	1/4” stainless steel tubing
5	1/4” plug valve	12	1/4” flexible tubing
6	1/4” micro metering valve	13	1/2” stainless steel tubing
7	1/4” union bonnet valve	14	3/8” NPT-1/2” connector

Figure 2-1. Installation Plumbing Diagram #1



Item	Description	Item	Description
1	Ball Valve	8	Male connector
2	Water trap	9	Bracket ”L”
3	Pressure regulator	10	Bracket “L”
4	Needle valve	11	Plastic tube
5	Plug valve	12	Flex line 3/8”
6	Union tee	13	Filter
7	Union cross	14	Male connector

Figure 2-2. Installation Plumbing Diagram #2

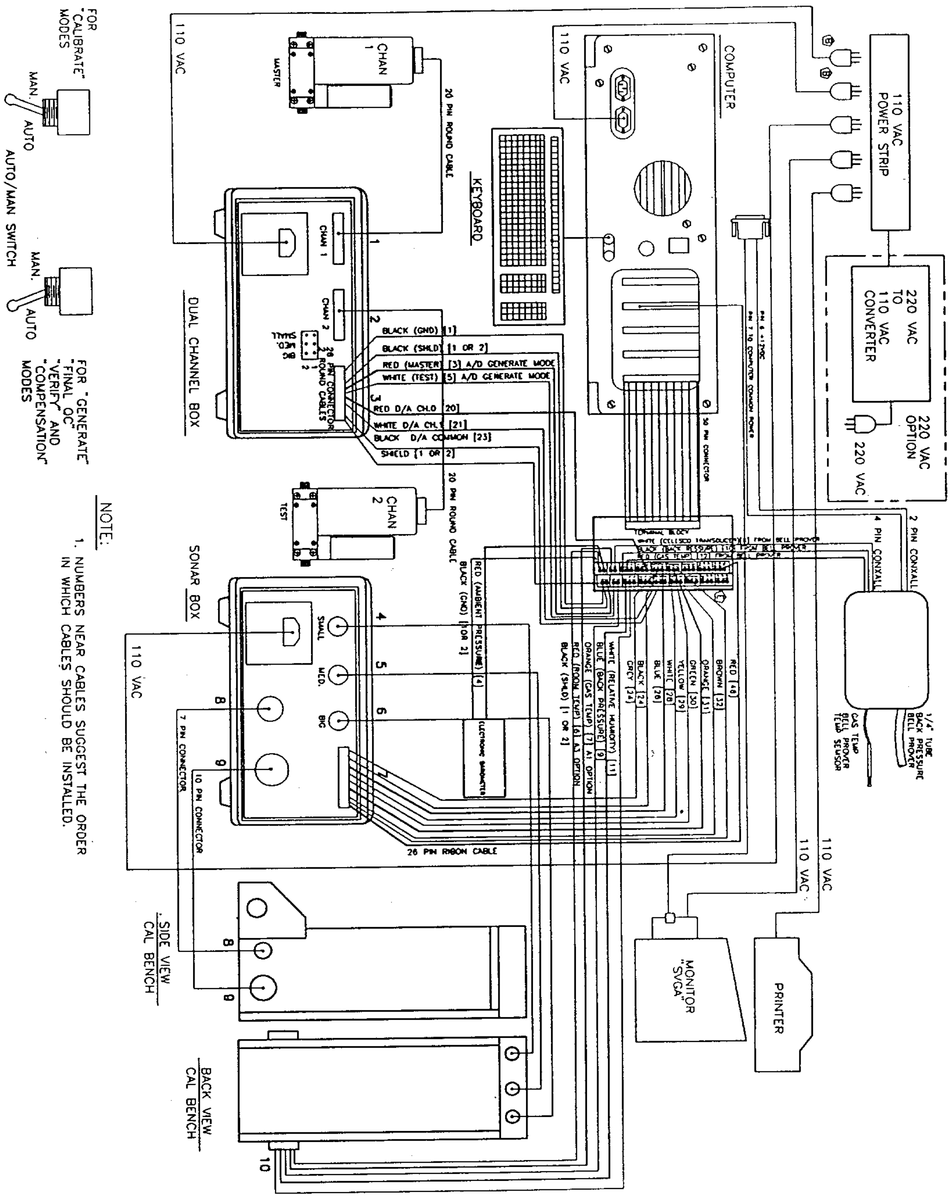


Figure 2-3. Component Interconnection Diagram

Bell Prover Option Installation

Plumbing

Bell provers are equipped with a 1.25” Female NPT tee to plumb the output of the Device Under Test (DUT) to the bell prover. We recommend plumbing at least 20 pipe diameters upstream and downstream from the DUT. Your work area must be large enough to accommodate the length of pipe and the DUT.

Recommended pipe size:

- no smaller than 0.5” for the 5 cubic foot bell prover;
- from 1.25” to 1.5” for the 20 cubic foot bell prover.

For convenience, shut-off valves can be plumbed in series for connecting and disconnecting purposes. One shut-off valve can be installed between the end of the air supply and the work bench. Another shut-off valve can be plumbed after a needle valve just prior to the DUT. To plumb the bell prover:

1. Run the tubing or pipe from the output of the last filter to the work area. End the run with a shut-off valve. If the run is long you may wish to place another water trap followed by a particulate filter.

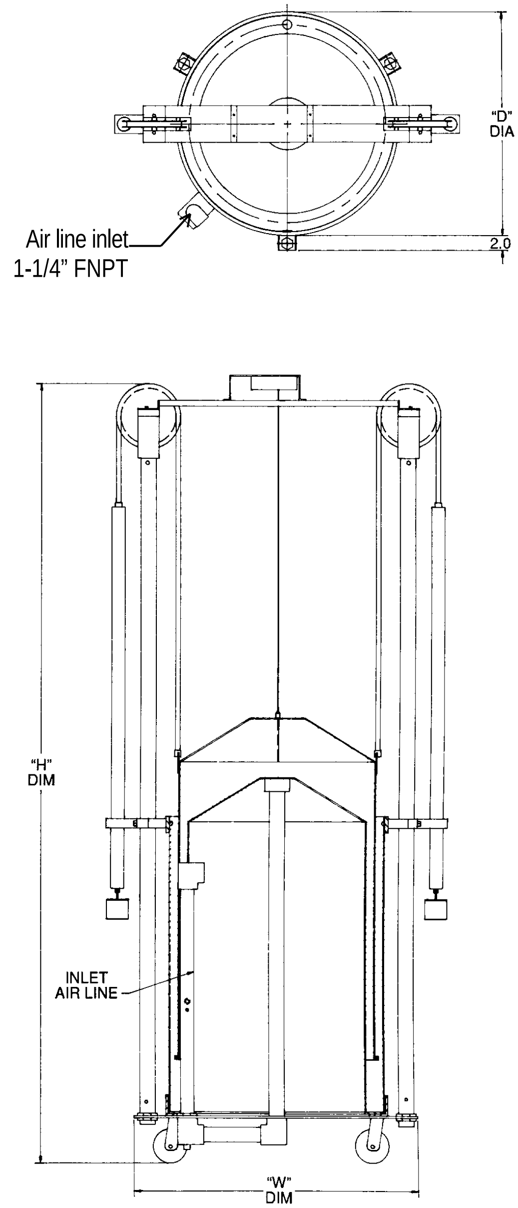
2. Place a high quality dual stage pressure regulator or two pressure regulators after the filters. Use regulators and gauges capable of controlling the line pressure.

3. After the regulator(s) place a tee branch. One leg of the tee will go to a large needle valve(s) capable of adjusting flow to 2500 SLPM. The other branch will bypass the needle valve and go to a shut-off valve. The output of the shut-off valve and the needle valve will go to a tee branch, continuing the run.

4. Run tubing or pipe from the tee branch to a second tee branch. One end of the tee branch will be an exhaust with a shut-off valve; the other end will continue the run to the DUT.

5. Plumb the DUT. You will need an assortment of fittings to accommodate the various fittings found on the devices you intend to calibrate.

6. After the DUT, run the tubing or pipe to the inlet of the 1.25” NPT tee on the bell prover.



Bell Prover Model	“W” Dim	“H” Dim	“D” Dia
MBP 5	30.5”	88.4”	24.0”
MBP 20	41.5”	108.6”	36.0”

Figure 2-4. Bell Prover Dimensions

Leveling

Three adjustable casters are mounted on the base of the bell prover. Once the bell prover is moved into place, adjust each caster up or down to level the tank. Use a torpedo level or a small carpenters level to check the tank level as the casters are adjusted. Do not move the bell prover once the tank is leveled. If the bell prover is moved, leveling is required.

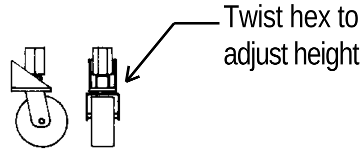


Figure 2-5. Caster Adjustment

Oil Installation

Verify the oil tank plug is installed and tightened on the bottom of the bell prover. Pour the bell prover oil into the tank down one side of the inner bell. Fill the tank to 5” below the rim of the tank. Clean up any oil spills. A smaller transfer container may be helpful in moving the oil from the oil supplier container to the bell prover tank.

Wiring

Warning

To avoid potential electrical shock, turn OFF system power before making bell prover connections.

Power for the bell prover electronics package is supplied from the Cal-Bench system computer. A cable with a 9-pin D connector on one end and a 2-pin circular connector on the other end interfaces the power of the computer to the bell prover electronics. If your system has a Cal-Bench and/or a second bell prover, the 9-pin D connector will have a power cable for each device. To connect bell prover input power:

1. Run the cable with the 2-pin circular connector to the bell prover electronics package. Plug and secure the connector to the prover electronics.

2. Plug the 9-pin D connector into the back of the system computer. Secure the D connector with the two mounting screws.

The output of the bell prover electronics package interfaces with the system A/Ds via a 25 foot cable with fly leads on one end and a 4-pin circular connector on the opposite end. (This cable may be factory connected to the electronics already.) To connect the bell prover output signal:

1. Connect the 4-pin connector to the prover electronics. Run the cable down the bell prover to the 50-pin terminal block on the side of the system computer.

2. Use a small screwdriver to open terminals 8, 10, and 12 on the terminal block. Terminals 1 and 2 are common. Connect the wires to the 50-pin terminal block as shown in the table below.

Bell Prover Wire Hookup Guide		
Color	**Pin #**	**Function**
White	8	Linear encoder output
Black	10	Back pressure output
Red	12	Gas temperature output
Shield	1 or 2	Cable shield

Systems with a second bell prover, QProver, will have a second 25 foot two conductor cable coming out of the 9-pin D connector with a 2-pin circular connector on the end to power the electronics package. The output for the electronics package for the QProver also has a four conductor cable with fly leads that interfaces to the A/D terminal block on the system computer. Connect the wires to the 50-pin terminal block as shown in the table below.

QProver Wire Hookup Guide		
Color	**Pin #**	**Function**
White	13	Linear encoder output
Black	15	Back pressure output
Red	17	Gas temperature output
Shield	1 or 2	Cable shield

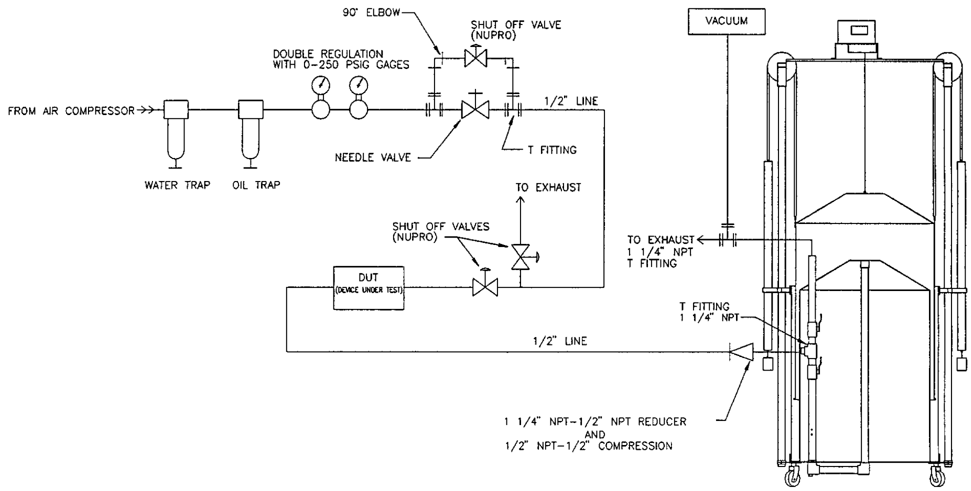


Figure 2-6. Five Cubic Foot Bell Prover Installation

Installation Notes

1. This plumbing diagram is one of many configuration a user might consider when plumbing a bell prover. The line should be as straight as possible.

Warning

You should provide a suitable exhaust system to prevent any safety hazards that may occur due to the output gas issuing into the work environment.

1. A pneumatic eductor is a good way to vent outlet gas. Use a vacuum to lower the bell.

2. Leak test the system frequently as Swagelok fittings, when changed, are prone to leaks. You may elect to use quick disconnect fitting to minimize leak potential.

3. Double regulation is strongly recommended.

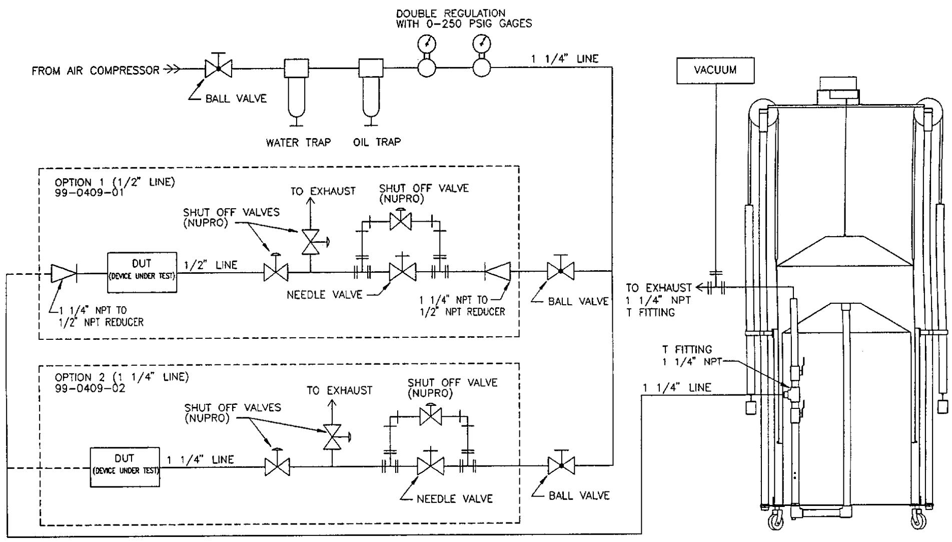


Figure 2-7. Twenty Cubic Foot Bell Prover Installation

Installation Notes

1. This plumbing diagram is one of many configuration a user might consider when plumbing a bell prover. The line should be as straight as possible.

Warning

You should provide a suitable exhaust system to prevent any safety hazards that may occur due to the output gas issuing into the work environment.

1. A pneumatic eductor is a good way to vent outlet gas. Use a vacuum to lower the bell.

2. Leak test the system frequently as Swagelok fittings, when changed, are prone to leaks. You may elect to use quick disconnect fitting to minimize leak potential.

3. Double regulation is strongly recommended.

Chapter 3 System Operation

Operational Overview

After completing the installation of your Cal-Bench™ system, you are ready to begin system operation. The sections in this chapter explain each of the main operational modes of the system software. Included are instructions for:

Page

This chapter provides complete and easy to follow instructions on the use of the Cal-Bench system. It is not intended to give specific instructions on methodology of calibrating any specific type or model of flow device. The user must consult the instruction manual of the Device Under Test for specific directions on calibrating that particular meter.

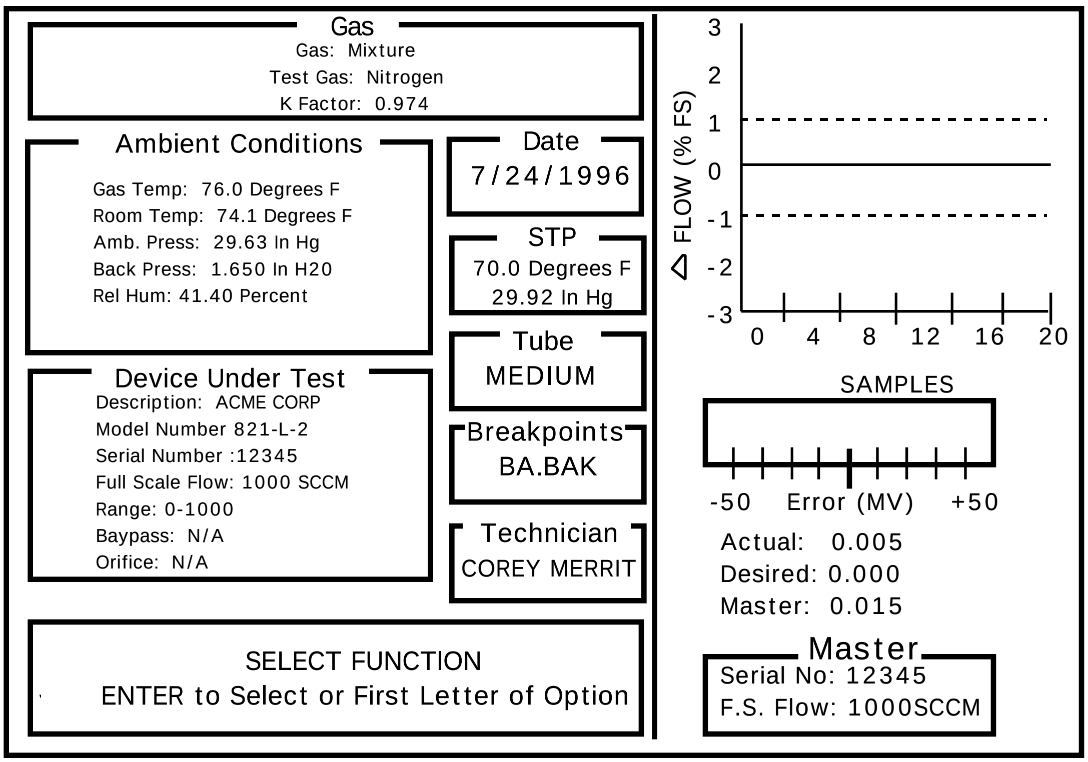
This software includes the main calibration program for operation of the Cal-Bench Primary Automated Gas Flow Calibration System. The software also includes look-up tables for the various gases you will be using in your calibrations. The program permits you to add gases or modify the gas table to suit your particular needs. It also permits storage and recall of the calibration records previously performed. By using the self-contained data base, you can retrieve calibration records by serial number and file name.

The Cal-Bench software program is operated from the computer hard disk drive. Backup software is provided on floppy disk. We recommend using the hard drive for saving calibration records.

Getting Started

The operating software uses a window-style interface. The ability to view all the appropriate calibration information at a glance enables you to quickly make data changes.

To begin with, you should become familiar with the basic display screen and specifically note the location of the Dialog Window. This window is used for all of the instructions and keyboard commands which will follow. (See below for screen display).

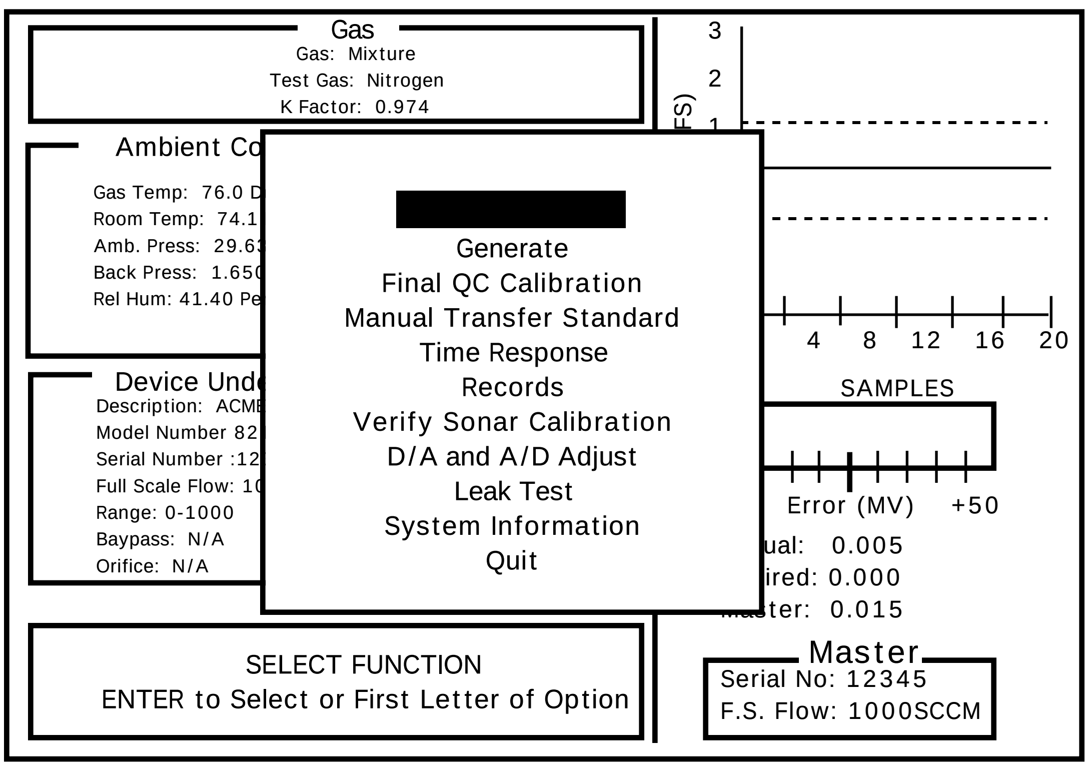


The titles and general descriptions used in the main window of the display screen are discussed on the following pages. Please become familiar with the information on the screen and where it is located.

Dialog Window The Dialog window, located in the lower left hand corner of the display screen, provides instructions to the user and offers a selection of choices. Each choice requires a simple one key command which are:

- first letter in the selection
- cursor up or down for selection
- ENTER to make selection
- ESCape when all entries have been completed

When the Cal-Bench system is activated, the first screen up will be the basic display screen with the addition of a superimposed window with a menu of the main calibration selections. These are the main operational modes of the software. There are four main calibration programs: Calibrate, Generate, Final Q.C. Calibration and Manual Transfer Standard. In addition are six support operations for verifying the operation of the Cal-Bench or additional sub-functions.



The program will automatically check today's date and the date tube recalibration is due. If the actual date is equal to the tube recertification date, the following message will appear in the center of the main screen:

```
Time to Recalibrate the Glass Tubes!
The Glass Tubes Were Last Calibrated  MM/DD/YYYY
The Recalibration Date for the Glass Tube is MM/DD/YYYY
Hit ESCape to Continue
```

This warning will provide you with notice of the need to recalibrate the tubes. See Chapter 4 for details on tube recalibration.

Gas Indicates information regarding the gas used in the flow meter, the calibration (test) gas, and the K factor of the actual gas relative to the calibration gas. The K factor is only used when calibrating thermal capillary tube mass flow meters and controllers. The program includes automatic selection of the actual gas, recommends various test gases, and automatically calculates the K factor. The Cal-Bench system is capable of calculating the K-factor for a mixture of up to four gases.

Caution

Calculating K-factors for more than three gases significantly increases the inaccuracy of the resultant K-factor. Sierra Instruments cautions against selecting a gas mixture of more than three gases.

Ambient Conditions The Cal-Bench system requires the following information on the ambient conditions at the time the calibration is performed:

- Gas Temperature
- Room Temperature
- Ambient Pressure
- Back Pressure
- Relative Humidity

This information is used within the program to calculate the speed of sound and convert from actual volumetric displacement to standard mass flow at the STP conditions utilized.

Device Under Test This window describes the flow device being calibrated. This section is basically set up for a description of a mass flow meter or mass flow controller. Not all information need be entered. Certain information is used by the program and must be entered; other information is for description purposes only and is saved as part of the calibration report. This information can be manually entered or retrieved from the calibration records data base. You must enter Device Under Test serial number and it's full scale flow for proper operation.

Date The date of the calibration is automatically entered

STP The conditions you wish to utilize for STP are shown.

Tube The tube used for the calibration test is displayed. During manual calibration, the user is free to select the tube for the test. During the Final Q.C. Calibration and Generate Mode, the software will automatically select the tube which best corresponds to the flow rate of the test being conducted.

Breakpoint Indicates which Breakpoint file is being used during the Generate Mode and Final Q.C. Calibration. This file lists the number and the individual points (as a percentage of full scale) to be used during the flow calibration.

Technician Enter the name of the calibration technician performing the calibration.

Master Displays the Serial Number and the Full Scale Flow of the Master mass flow controller used during the "Generate" and "Final Q.C." modes.

Graph The graph in the upper right hand corner of the display screen provides a visual indication of the error as a percentage of full scale over time. This is used to determine if any sudden acceleration occurred during the test which could nullify the results.

Error (mv) This window is utilized when using the Cal-Bench as a voltmeter for setting the specific output voltage of the Device Under Test.

Software Program Information

The following files are used by the software program and are contained on the disk:

Sierra.exe	Main Program
BA.BRK	Typical Break Point file
CDDF.CFG	Contains information specific to your Cal-Bench system
Display.CFG	Enables use of VGA display and expanded memory
Color.CFG	Configure Display colors
Report.CFG	Configure Calibration Report printout
Custom.CFG	Custom configure Calibration Report printout
Printer.CFG	Contains printer driver library and printer driver
Gxprint.txt	List of printer drivers
Gxprint.gxl	Printer driver library
Bit8x8.gft	Large fonts file
Bit5x8.gft	Small fonts file
Herc.BGI	Screen driver for Hercules
Gas.TBL	Gas table of K factors for 135 gases
A2Dtest.exe	Test program used in calibration procedures

In addition, each calibration record is stored on the disk in its own subdirectory.

The computer supplied with the Cal-Bench™ system can be used for other purposes although the Cal-Bench program will not run while other programs occupy memory. It is important that all TSR programs be removed from memory when using the Cal-Bench program.

Note

The display screen can be printed at any time by pressing the "Ctrl" and "P" keys at the same time. If a test is underway, the screen prints at the completion of the test.

Master Meter

If your Cal-Bench system is equipped with the Generate Mode option included with the system are three Side-Trak Mass Flow Controllers. These instruments serve as the "Master" flow controllers used during the Final Q.C. Mode calibration of rotameters, flow meters, flow controllers and for the Generate Mode. Three Side-Traks are provided to offer a wide variety of flow ranges to choose from. All "Master" flow controllers are calibrated for Nitrogen. (Nitrogen is the standard upon which most calibrations are based.) When a "Master" flow controller has been selected for use, it must be properly identified by the Cal-Bench program in the Master Window.

Master Window is located in the lower right-hand corner of the screen. Information is entered using the O)ther menu choice and then selecting the M)aster menu choice. This procedure is critical in order for the Final Q.C. Mode and the Generate Mode to function properly. The program must have the full scale flow values of both the “Master” flow controller and of the “Device Under Test” in order to generate the appropriate amounts of flow while calibration is in process.

In cases where a calibration gas other than Nitrogen (or Air) is used during the Final Q.C. Mode and the Generate Mode, the full scale flow value of the “Master” flow controller must be “adjusted” to account for the difference in full scale flow between the actual calibration gas and Nitrogen (N2). This is because all “Master” flow controllers are calibrated for N2, and thus, will not reflect the correct flow rate if a gas other than N2 (or Air) is used during calibration.

To compensate for gases other than Air or Nitrogen you must determine the gas K-factor for the actual calibration gas relative to N2 and multiply it by the “Master’s” original full scale flow value. The result will be the “Master” flow controller’s “adjusted” full scale flow value. The “adjusted” full scale flow value is then entered in the Master Window in place of the full scale flow value indicated on the Master meter. Note that the Master meter is nothing more than an automatic valve used to attain the desired breakpoint flows. The flow rate is measured using the Cal-Bench system, rather than using the flow value indicated by the “Master.” In Generate Mode the Cal-Bench measures the flow rate and controls the mass flow controllers valve. This means that the Master meter need not be precisely calibrated. It only has to be capable of “creating” the desired full scale flow function as a flow controller and hold the flow constant.

When using the Final Q.C. Mode on a mass flow controller the Master meter is not physically used. It is necessary, however, to ensure the Master Meter Window indicates the same full scale flow as the Device Under Test (DUT). Even when doing a Final Q.C. on a flow controller with a full scale of 134 SCCM you will need to enter 134 SCCM as the full scale of the Master.

Two examples are provided below:

Please note that there will be two gas K-factors used in this case. The gas K-factor for the “Device Under Test” (which is located on screen in the Gas Window) is automatically calculated by the Cal-Bench program. NO CHANGES SHOULD BE MADE TO THIS K-FACTOR.

The other K-factor concerns the full scale flow value for the “Master” controller which is “adjusted” and then entered via the Master Window.

Example #1:
In this example, the “Device Under Test” will be calibrated for 200 SCCM of Argon. The actual calibration gas will also be Argon. This will make the gas K-factor for the “Device Under Test” equal to 1.00. (NOTE: The gas K-factor for the “Device Under Test” is automatically entered by the Cal-Bench program and no changes are required when you select the test gas and the calibration gas to be the same.)

The “Master” flow controller, however, is calibrated for Nitrogen (as are ALL “Master” flow controllers). As such, the “Master’s” full scale flow value must be recalculated to correct for the difference in mass between N2 and the actual calibration gas (in this case, Argon). This calculation must be reflected in an “adjusted” full scale flow value that is entered in the Master Window.

To determine the “adjusted” full scale flow rate for the “Master” controller:

1. Find the K-factor for the actual calibration gas relative to N2. You can use the Cal-Bench to do this or you can use the K-factors listed in the Gas Tables in the Side-Trak Manual. (For Example, the Side-Trak manual lists 1.45 as the K-factor for Argon relative to N2.)

2. Multiply the relative K-factor times the “Master” flow controller’s full scale flow value for Nitrogen. (This value is listed on the “Master” flow controller’s identification label). The result is the “adjusted” full scale flow value for the actual calibration gas. (For example, if the “Master” flow controller’s full scale flow value for Nitrogen is 200 SCCM, the “adjusted” full scale flow value would be 200 times 1.45, or 290 SCCM (Argon).

If the actual calibration gas for Example #1 is Argon, the "adjusted" full scale flow value for the "Master" flow controller would be 290 SCCM. This value is entered in the Master Window, causing the "Master" flow controller to generate the correct flow rates, while using Argon as the actual calibration gas.

Example #2:
In this example, the "Device Under Test" will be calibrated for 1000 SCCM of Silane (SiH4). The actual calibration gas to be used will be Nitrogen (N2). The gas K-factor for the "Device Under Test" will then be equal to 0.60. (Remember, the gas K-factor for the "Device Under Test" is automatically entered by the Cal-Bench program. No changes should be made to this K-factor.)

In example #2, the "Master" flow controller is calibrated for 2000 SCCM of N2. To calculate the "adjusted" full scale flow value for the "Master" in this circumstance, the relative K-factor for Silane to N2 must be determined. Looking in the Gas Tables in the Side-Trak manual, the relative K-factor for Silane to N2 is found to be 0.60.

Once the relative K-factor is determined, the K-factor is then multiplied by the "Master" flow controller's full scale flow value for Nitrogen, which in this case is 2000 SCCM. 2000 (SCCM) times .60 equals 1200 (SCCM). Thus, the "adjusted" full scale flow value for the "Master" flow controller Example #2 is 1200 SCCM. This is the value that should be entered into the Master Window.

Data Input

When a particular calibration sub-program is selected, all necessary information must be loaded into the program and displayed on the screen. The calibration information will be retained on the screen while you change between calibration sub-programs.

Once a calibration sub-program is selected, the command window located in the lower left hand corner of the display screen will indicate:

```
XXXXXXXX PROCEDURE

G)as   D)evice   T)ube   O)ther    ENTER     ESCape
```

The first line of the Dialog Window will display the selected procedure (Calibrate, Generate, Final Calibration, or Manual Transfer Standard will replace XXXXXXXX on our example). The second line is used to select that section of the data which will be entered. You should proceed from left to right, entering G for the selection of the type of gas the flow meter will be calibrated for.

Gas Mixtures

G)as. The Cal-Bench system is capable of calculating the K-factor for a mixture of up to four gases, however, calculating K-factors for more than three gases significantly increases the inaccuracy of the resultant K-factor. Sierra cautions against selecting a gas mixture of more than three gases. Pressing G)as brings up a window in the center of the screen that lists a variety of gases present in the data base. Use the Up/Down or PgUp/PgDn arrow keys to select the gas. To speed search, you can enter the first letter of the gas and the program will automatically bring up the list of gases which start with that first letter.

After the gas is selected, the screen will ask for “Percentage of” the gas. This is very useful if the flow device is calibrated for a blend or mixtures of gases. The default condition is 100%; if a gas mixture is utilized, simply enter the percentage of the first gas. The first gas entered should always be the highest percentage unless another gas in the mixture will be used as the test gas.

```
Percentage of Nitrogen, N2(100.00): 85
```

This entry indicates there will be a gas mixture containing 85% Nitrogen. When formulating a gas mixture, select the major gas composition first.

The next screen will display the composition of the gas mixture as determined to this point:

```
Gas Mixture
85.00% Nitrogen, N2
```

The Dialog Window permits you to press ENTER to continue with formulating the gas mixture or ESCape to re-enter the composition.

Continuing with the gas mixture, the Dialog Window will then read:

```
SELECT GAS #2
PgUp  PgDn  First Letter  Enter to Select
```

After the second gas has been selected, the window will display the maximum percentage of the second gas. This will be 100% less the concentration of the first gas (15% in this example). This entry can be selected if there is a two composition gas. The program permits calibration of multiple gas mixtures with up to 4 components.

Once the final gas composition has been determined, the Command Window will display:

```
SELECT TEST GAS
Hit Enter when done
```

Gas Table

A window indicating a selection of test (calibration) gases will also appear. The choice of nitrogen is always available as the test gas. Use up/down arrows to select test gas. Press ENTER to continue.

The program includes a data base file of various gases; the file is titled “gas.tbl” The gas table can be modified using any ASCII text editor or word processor. See Appendix A for details on modifying the gas tables.

Device Selection

D)evice. Information on the device being calibrated is entered. The Dialog Window prompts the selection of the Device Under Test as either:

```
              Select Device Under Test
N)ew    C)hange Current     E)xisting      ESCape
```

N)ew refers to a flow meter that is not in the calibration record data base.

C)hange Current refers to the currently displayed record. C)hange current will not be displayed in the command window if information is not currently in the Device Under Test window.

E)xisting refers to a flow meter which has previously been calibrated and there is a record of this calibration in the database.

If you select an E)xisting record, the Serial number of the Meter will be requested and the pertinent information on that device will be retrieved from the database.

If the meter is not in the database, the following information of the Device Under Test (DUT) is requested:

- Description: Any description of the DUT.
- Model Number: Model Number of the DUT.
- Serial Number: The serial number of the DUT must be entered. This information is utilized for storage of the calibration data. The Serial number entered must be 6 characters or less due to the restrictions imposed by DOS. This Serial Number is used to create the sub-directory for storage of calibration data.

- Full Scale Flow: Indicate maximum flow rate of the DUT. Full scale flow rate must be entered for software to work properly.

- Range: Enter the range of the DUT.

- Bypass: If desired, a code for the bypass size can be entered.

- Orifice: If desired, the valve orifice size can be entered.

Enter the requested information in the windows as it appears on the screen. Each time the information is entered, that information is displayed on the screen.

Not all information in the Device Under Test section is required. The following chart identifies the required inputs.

Field Required for Calibration

Description	No
Model Number	No
Serial Number	Yes
Full Scale Flow	Yes
Range	No
Bypass	No
Orifice	No

From the main screen, any information listed under the Device Under Test Section can be updated by pressing D)evice and C)hange. The following will appear in the Dialog Window:

```
D)escription    M)odel No   S)erial No    F)low
R)ange    B)ypass    O)rifice    ENTER to Accept
```

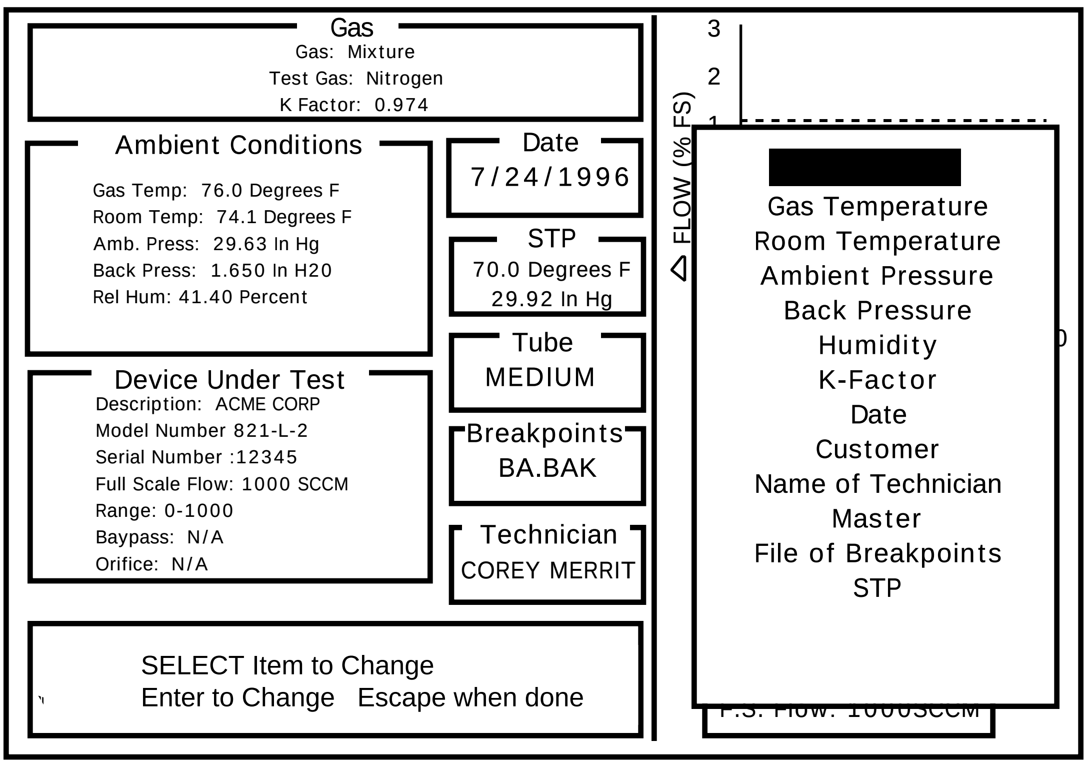
Enter the information requested in the window that appears in the middle of the screen.

Tube Selection

T)ube permits manual selection for one of the three tubes to be used during the calibration. When operating in “Generate” or “Final Q.C. Calibration” modes, the program will automatically select the tube that will provide the optimum performance. The user can override the automatic selection of the tube but does so at the risk of too rapid a piston acceleration and loss of mercury if the selected tube is too small. Conversely, a very long test period will occur if the tube size is too large.

This entry also permits the optional selection of a Bell Prover System for flow rates greater than those handled by the Cal-Bench tubes. Consult Sierra about automating your Bell Prover System.

O)ther asks for selection of the remaining items on the screen or selection of the units of measurement. The following screen is displayed when O)ther is first pressed:



Use the Up/Down arrow to select the item to be entered or modified. Optionally, the first letter of the selection can also be entered. Press ESC when finished.

Units select the units of measurement that best suit your individual circumstance. The default units are listed in the CDDF.CFG file. See Appendix A for instructions on modifying this file. When "Units" is selected, the following window is displayed:

```
Temperature in Degrees F
Pressure  in Hg
Back Pressure in H2O
Flow Rate  SCCM
```

Use the Up/Down arrow keys to select which units of measurement to change and ENTER to change the units of measurement. The following units of measurement can be selected:

- Temperature: °F, °C.
- Pressure: mm Hg, In Hg, PSIA
- Back Pressure: mm Hg, In Hg, In H_2O, PSIA
- Flow Rate: SCCM, SLPM, SLPH, SCIM, SCFM, SCFH, Other

In addition, the operating software permits you to custom define your own units of flow (see Appendix A, CDDF.CFG File).

Once you have selected the units to be used, press ESCape to continue with the other selections available.

Unless your Cal-Bench system is equipped with automated inputs, you must enter the following ambient conditions:

1. Gas Temperature
2. Room Temperature
3. Ambient Temperature
4. Back Pressure
5. Humidity

This can be done by a manual input or with the use of automated inputs using the A/D converters provided with the Cal-Bench system hardware. See Appendix A for instructions on hooking up your own automated input functions. Modifications of the CDDF.CFG file are also required (See Appendix A).

K-factor command allows manual entry of the K-factor in place of using the value calculated by the program. This would be used any time you choose a different K-factor as determined by another manufacturer of thermal capillary tube mass flow meters and controllers.

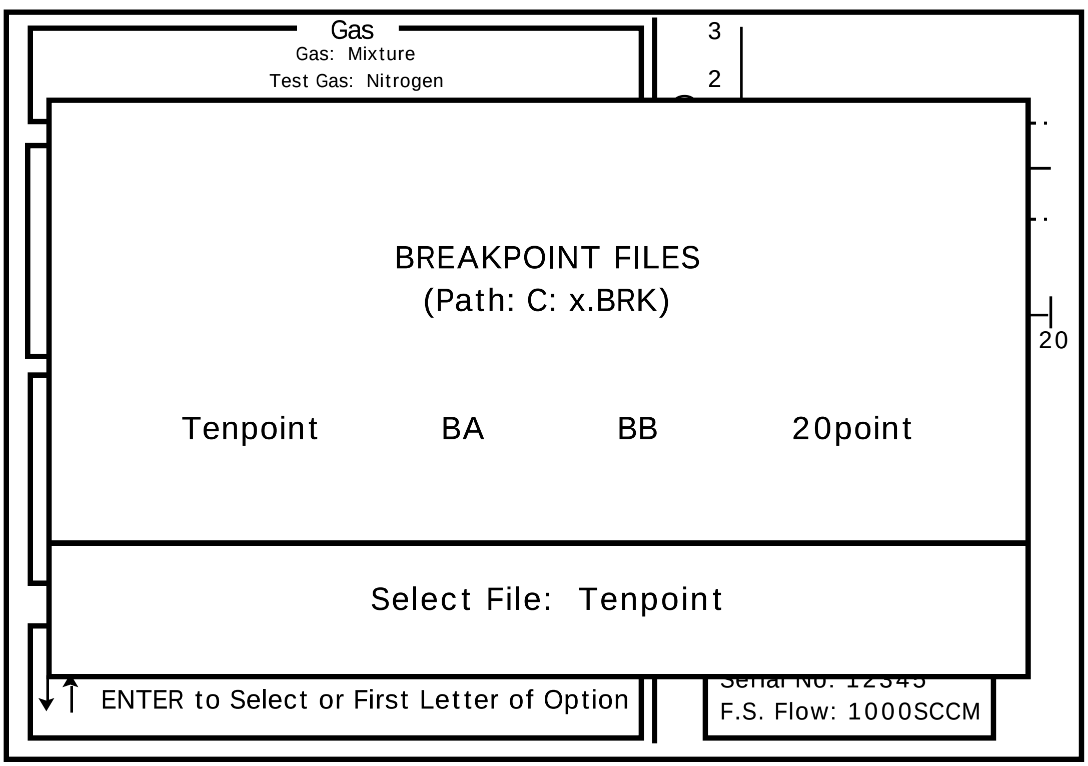
Date of the calibration. This date is automatically obtained from the clock/calendar in the Cal-Bench computer.

Customer may be any desired entry.

Name of Technician performing the calibration is entered and saved with the calibration record.

Master is the Serial Number and the full scale flow range of the Master Mass Flow controller. This is used in "Generate Mode" operation. The information is stored with the calibration records.

File of Breakpoints Various Breakpoint files can be pre-defined. This refers to the points at which flow calibration is done. Often this is at 0, 25%, 50%, 75%, and 100% of full scale flow. Other flow meters may be calibrated at 0, 15%, 25%, 65%, and 100% or you may wish to check the calibration at every 10%. The Breakpoint file allows you to develop your own calibration points. See Software Appendix A for instructions on setting your own Breakpoint files. You may have up to 32 breakpoints in any file. When this selection is made, the screen displays a list of Breakpoint Files stored on the default directory. Select the file you want and press ENTER to proceed:



STP Enter or modify the standard temperature and pressure conditions used for the calibration. Some industries use 0°C, other industries use 60°F, 70°F and 75°F. The default STP conditions are listed in the CDDF.CFG file and can be modified, (see Appendix A).

When you have completed all information entries, press ESCape to return to the main display screen. Be sure that all relevant information is entered. If information is missing, the following error message will appear:

```
ERROR!
User MUST Enter data as shown
hit ESCape to continue
```

When this error message is displayed, press ESCape to remove the window and re-verify the information in all fields.

Calibration Mode

This is a Manual calibration mode. The Cal-Bench™ system will display the mass flow rate in the units selected. The flow rate to the flow Device Under Test must be manually controlled. There is no storage of calibration data, print out of reports, or flow rate generation with this mode of operation. The Breakpoint files are not utilized in this mode.

Calibrating a Mass Flow Meter

To calibrate a mass flow meter, the flow rate to the meter must be controlled with the use of a needle valve or other limiting device.

To calibrate a mass flow controller, the setpoint adjustment pots of the 902 Control Box Assembly can be used to set the flow rate through the device. Make sure that the switches of the Control Box Assembly are set to “Manual”.

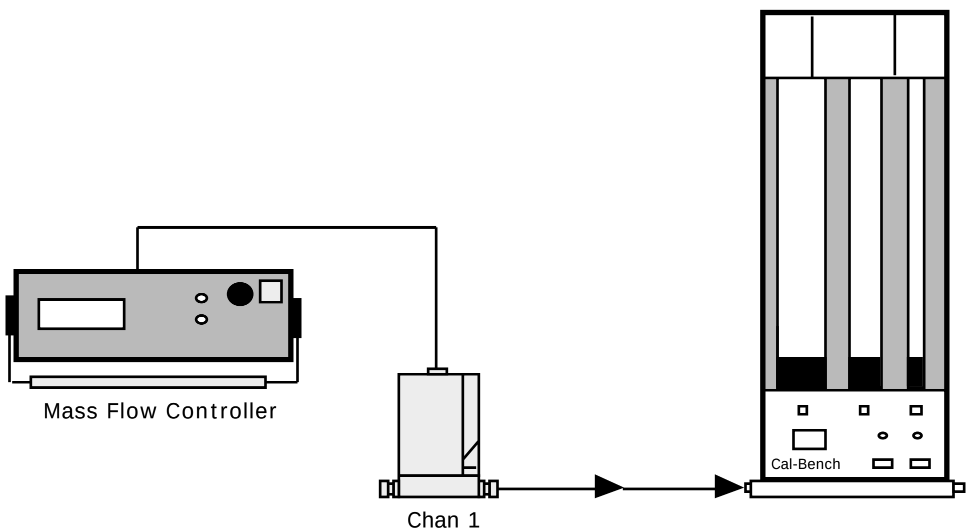


Figure 3-1. Manual Calibration Set Up

A voltmeter or display from the Control Box Assembly is required to provide the *indicated* flow rate from the meter with the Cal-Bench providing the *actua*l flow rate.

To proceed with the manual calibration, select the Calibration Mode from the “Select Function” window. If you are not in this mode, press ESCape until that window appears. Press ENTER to proceed into the “Calibration Mode” and ensure that all the information indicated on the main display screen is correct. The first line in the Dialog Window should read:

```
CALIBRATE PROCEDURE
G)as   D)evice   T)ube   O)ther  ENTER   ESCape
```

Press G, D, T, or O to change any information on the main screen. Press ENTER to proceed or ESCape to abort.

In the next screen, the Dialog Window instructs you to set the switch position of the Control Box Assembly:

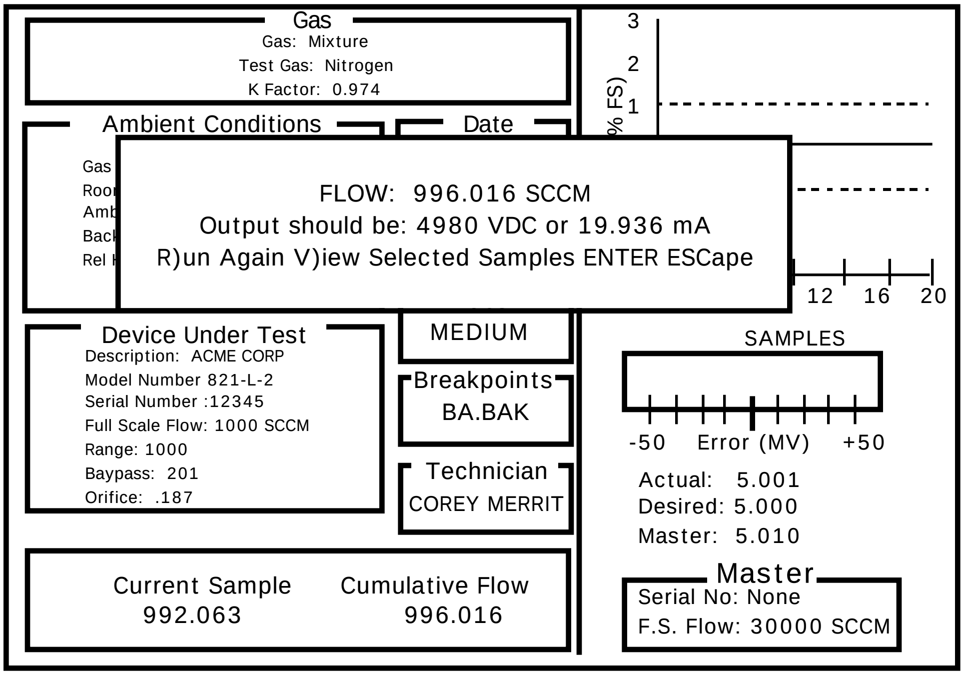
```
Place the Auto/Manual switches in the MANUAL mode
ENTER to Continue       ESCape
```

After ENTER is pressed, the gas flowing through the Cal-Bench system will be diverted into the tube that has been selected. The Cal-Bench will begin to measure and report the flow rate. The Dialog Window will show the flow rate measured during the Current Sample and the Cumulative Flow rate over the entire sampling period.

```
Current Sample     Cumulative Flow
   XXX.XX              XXX.XX
```

During the test, the flow graph in the upper right hand corner of the display screen will indicate the percentage change in the flow rate of the current sample, compared to the cumulative value. It is displayed as a percentage of the full scale reading of the Device Under Test. Some minor variations are expected and indicate normal fluctuations in flow rate. It is our recommendation that if readings are outside the dashed lines on the chart at +1% and –1% that the reading be discarded and the calibration be repeated. This would indicate that acceleration or non-uniform flow occurred during the test period. If the area above and below the 0% line are equal, you may assume that the cumulative flow is valid and accept the test. Typical causes of erratic readings are "noisy" flow meters or dirty glass tubes or mercury.

At the end of the test period, the following screen will be displayed:



V)iew allows you to select a range of samples from the test. When V)iew is selected an adjustable window is displayed on the graph in the upper right corner. Use the up/down arrow keys to move the right bracket. Use the left/right arrow keys to move the left bracket. The flow displayed in the center window will adjust according to the samples selected.

The test can either be R)un again at the same manual setting or you may return to the main selection menu by pressing ESCape.

Aborting the test

You can abort any time during the test by pressing the space bar. The display will then give the flow measured by the Cal-Bench system up to the time the test was aborted.

During the test, the operator can adjust the potentiometers in the Device Under Test to set the output of the meter being calibrated to match the true flow measured by the Cal-Bench system. Consult the instruction manual of the device you are calibrating for directions on the proper method of calibrating the device.

Generate Mode Operation

The optional feature, "Generate Mode" of the Cal-Bench™ system will automatically generate a precise gas flow using the primary calibration tubes in a closed loop feed back mode with one of the Master mass flow controllers configured as a precision control valve. Operation in this mode eliminates the manual valve adjustment. The Master mass flow controller should be positioned in series with the flow device being calibrated as shown in the following illustration:

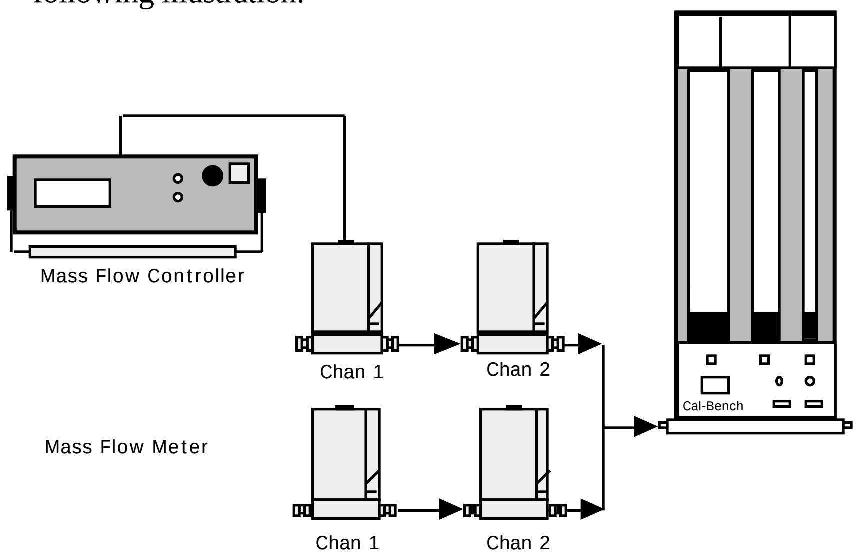


Figure 3-2. Generate Mode Calibration Set Up

If the Device Under Test is a mass flow controller, it is best to disable the valve by mechanically opening it, rather than operating the valve in the "purge" mode. Operating the valve in the "purge" mode will overheat the valve which may cause a shift in zero and calibration during the test. Consult the manufacturer of the mass flow controller for the proper method of mechanically disabling the valve.

Generate Mode activates the on-screen voltmeter that displays the actual voltage from the flow meter and the desired voltage output that will correspond to the actual flow rate measured by the Cal-Bench system. In using the Generate Mode, the Cal-Bench will first generate a precise flow rate using the control valve of the Master mass flow controller. The Cal-Bench system will measure the actual gas rate flowing through the appropriate tube and the output voltage from the Device Under Test. At the end of the run, the program will instruct you to adjust the appropriate potentiometer in the mass flow meter so that the voltage from the meter under test will match the actual flow measured by the Cal-Bench system.

To enter the “Generate Mode” return to the main menu screen which lists the various operational modes of the Cal-Bench Software and select G)enerate. Check all the data on the display screen, and particularly the information on the Master, for accuracy. Press ENTER to proceed.

Observing the instructions in the Dialog Window in the lower left corner of the screen, you will first be instructed to:

Place the Auto/Manual Switches in the AUTO mode ENTER to Continue ESCape

followed by:

Turn Off Gas and Monitor Zero ENTER To Continue ESCape

Use the voltmeter display located on the right side of the screen. This will give you the actual no flow voltage and the desired voltage (in this case zero). The display indicates the actual voltage output from the mass flow meter. Adjust the zero potentiometer of the Device Under Test to read between 0.001 and 0.008 volts and press ENTER to continue.

Note

Do not "bury the zero" by adjusting the zero pot to read zero. The A to D converters used in the Cal-Bench system are ranged for 0-10 VDC and will not read below zero.

The next instructions in the Dialog Window are to:

Turn on Gas to Adjust for Full Scale ENTER to Start Flow   ESCape

Press ENTER once you have opened all appropriate gas valves. The next instructions in the Dialog Window are to:

Adjust Full Scale Value to 5.000 VDC ENTER to Continue   ESCape

Observing the voltmeter display, the actual voltage and the desired voltage (5.00 volts) will be indicated. Adjust the Span potentiometer of the Device Under Test to read 5.00 volts. The purpose of this step is to ensure that the Device Under Test can attain the desired full scale flow. This is a preliminary test and this data is not part of the calibration record.

After establishing that full flow through the Device Under Test can be achieved, the stabilization time period can be adjusted.

This represents the time period between changing the flow rate of the master and initiating flow into the tube. The mass flow controller will take a maximum of 1.5 seconds for flow to stabilize. The response time of the Device Under Test must be added to the response time of the Master and sufficient stabilization time specified.

```
15 Sec Between Breakpoints
C)hange    ENTER    ESCape
```

Press C)hange to change the flow rate to any time period between 5 and 1000 seconds.

Once this time period is selected, the program will proceed to generate the first flow rate. The Dialog Window will confirm the first breakpoint flow calibration displaying:

```
Flow   XXXX SCCM  (25%)  using YYYYY Tube
C)hange  T)ube     ENTER to Continue    ESCape
```

This permits you to manually change the generated flow rate or the tube to be utilized. ESCape returns you to the Select Procedure Menu.

Using the Master mass flow controllers, the program will proceed to generate the specified flow. The generation of the flow rate is an iterative process requiring several attempts. When the actual flow rate is within 2% of the requested flow rate, the command screen will display:

```
Error of X.XX is within limit
```

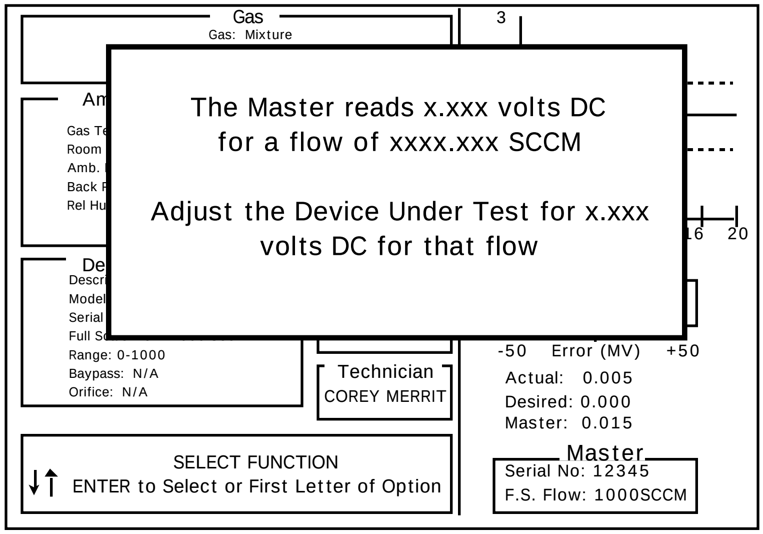
and:

```
Full Run for Maximum Accuracy Follows Delay
(Prepare to adjust the XX% Pot)
```

The flow can be aborted by pressing the space bar. If, after ten attempts to obtain the specified flow, the measured flow rate is not within 2% of the specified flow rate, the Dialog Window will display:

```
Error of X.XX%  is NOT WITHIN Limit
R)un Again   ENTER to Continue   ESCape
```

The program will then maintain the set point to the mass flow control valve and generate the desired flow rate. The Cal-Bench system then measures the actual flow and monitors the voltage output of both the Master flow control valve and the Device Under Test. After the completion of each run the following will be displayed:



Using the voltmeter displayed on the screen and the manufacturer's instruction manual, adjust the potentiometers in the Device Under Test to obtain the specified output voltage. See the instruction manual of the DUT for calibration instructions and location of the potentiometers. While adjusting the DUT, it is important to monitor the flow rate and the voltage output of the Master to ensure that the flow rate remains constant.

The program will continue until all of the calibration points specified in the Breakpoint file are completed.

After performing the calibration, the data can be viewed or printed. See Records, for information on record handling.

Final Q.C. Calibration

The Final Q.C. Calibration Mode is excellent for checking the calibration of a mass flow controller and performing pre-calibration (as received) checks. In this mode, the Cal-Bench gives a setpoint to the mass flow controller, reads the voltage output signal from the controller and compares it with the actual flow measured by the Cal-Bench system. The program displays the actual calibration data for the device and displays the error as a percentage of full scale. This data can printed or stored on disk for future reference.

There are two main operational modes with this program, **Regular** or **Automated**. In the Regular mode, the operator has the option of repeating any individual test; while in the Automated mode, the entire flow procedure is completed without operator intervention.

To perform the Final Q.C. Calibration, the Device Under Test should be connected to the Cal-Bench system using either one of the following illustrations:

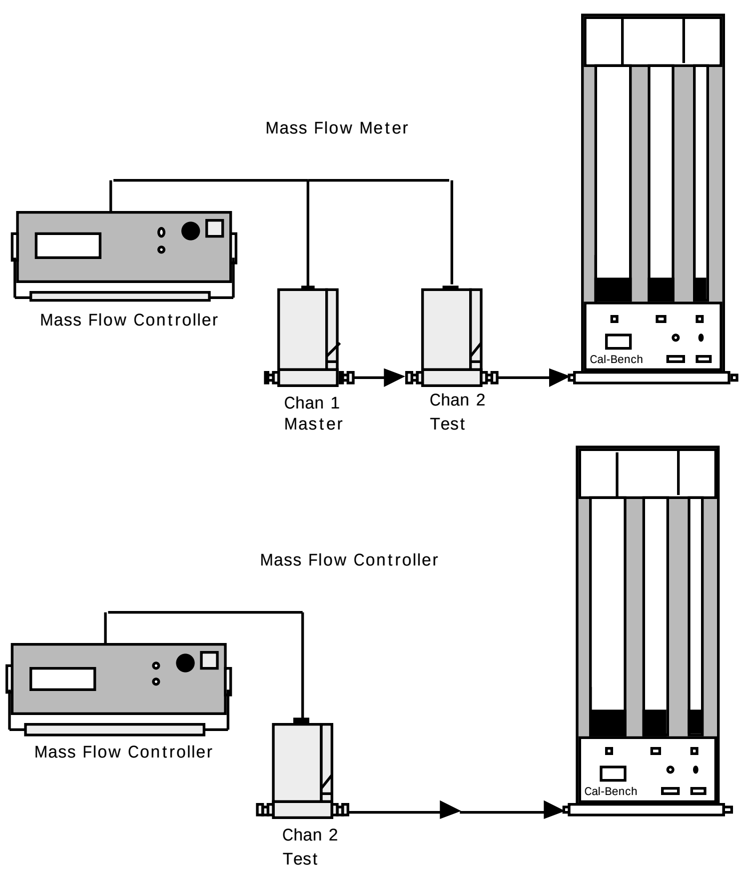


Figure 3-3. Final Q.C. Calibration Set Up

Enter the main menu and select F) or move the up/down arrow keys until "Final Q.C. Calibration" is highlighted. Check or revise all the information displayed on the display screen and press ENTER to continue. The Dialog Window will then display:

R)egular A)utomatic N)on- Electrical Output Device ESCape

Select one of the following:

- **A)utomatic** to obtain the calibration data without operator attention.
- **R)egular** mode which permits you to individually approve or rerun each individual test.
- **N)on-electrical Output Device** is utilized for calibration of a rotameter or other flow device which does not provide an electrical signal to the Cal-Bench. This mode requires the operator enter the flow rate measured by the non-electric flow device.

The first instructions in the Dialog Window are to:

Place the Auto/Manual Switches in the AUTO mode ENTER to Continue ESCape

followed by:

Turn Off Gas and Monitor Zero ENTER To Continue ESCape

This step is optional, depending on your specific requirements. If you are intending to obtain "as received" calibration data, do not adjust the zero.

The next instruction in the Dialog Window is to:

```
Turn On Gas to Monitor Full Scale
ENTER To Start Flow   ESCape
```

Again, this step is optional depending on the results you wish to obtain. You may want to immediately reject the calibration if either the zero or full range value is unacceptable.

Next, following the instructions in the Dialog Window select the time period between breakpoints; this is selectable between 5 and 1000 seconds. This is the stabilization time before performing a test after a change in flow rate.

In the Regular mode, the Dialog Window will then confirm the first Breakpoint flow by displaying:

```
Flow XXX.XX SCCM (25%)  using Small Tube
C)hange   T)ube   ENTER to Continue   ESCape
```

If desired, you can manually enter the flow rate you want to check by pressing C)hange and entering the new flow rate. This step is bypassed in the Automatic mode as the program proceeds with the Final Q.C. Calibration at the points predefined by the selected Breakpoint file.

The program will then give the mass flow controller the first set point listed in the Breakpoint file. The Dialog Window will give the flow rate of the Current Sample plus the Cumulative Flow. The deviation graph will plot the change in flow rate in the upper right hand corner of the screen.

```
Current Sample   Cumulative Flow
   XXX.XXX          XXX.XXX
```

In the Automatic mode, after completion of the run at the first breakpoint, the program will proceed to the remaining break points. For the Regular mode, at the end of the run, a window will appear in the center of the display:

```
(25%) FLOW:      249.114 SCCM
Output Should be: 1.246 VDC or 7.986 mA
R)un Again    ENTER to Accept    ESCape
```

R)un will run the test again at the same breakpoint, ENTER will accept that run and proceed with the next breakpoint, and ESCape will exit the "Final Q.C. Calibration." After completion of running the mass flow controller at all of the breakpoints, you will then have the option to:

```
A)dd Comments    D)one
```

A)dd Comments will permit you to enter up to three 80-character lines of comments, that are saved as part of the calibration record and appear on the next calibration. If you A)dd Comments, you will have the opportunity to review all three lines of comments and if desired, C)hange them.

After completion, the data can be viewed, saved or printed.

Final Q.C. Calibration of a Non-Electrical Output Device

Cal-Bench can be used to calibrate rotameters or other flow devices that have a non-electrical output. The flow meter being calibrated is placed in series with a Master mass flow controller that has a full scale range equal to, or greater than, the device being tested. (See Figure 3-4.)

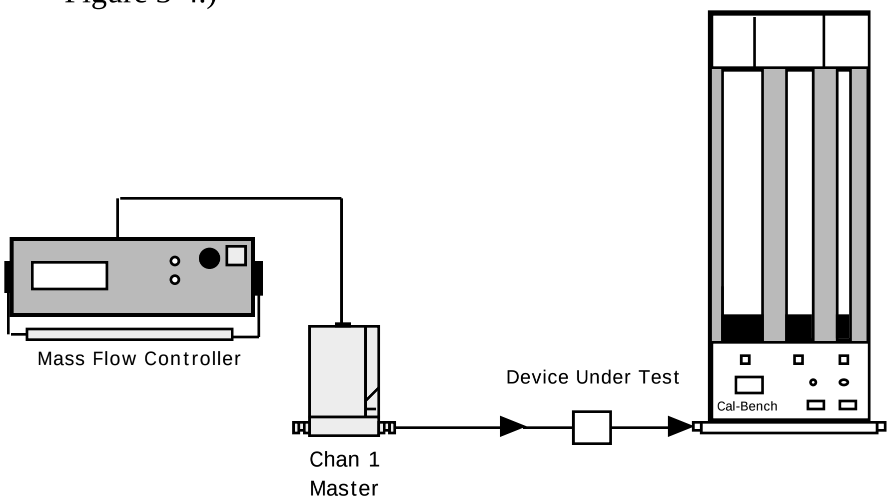
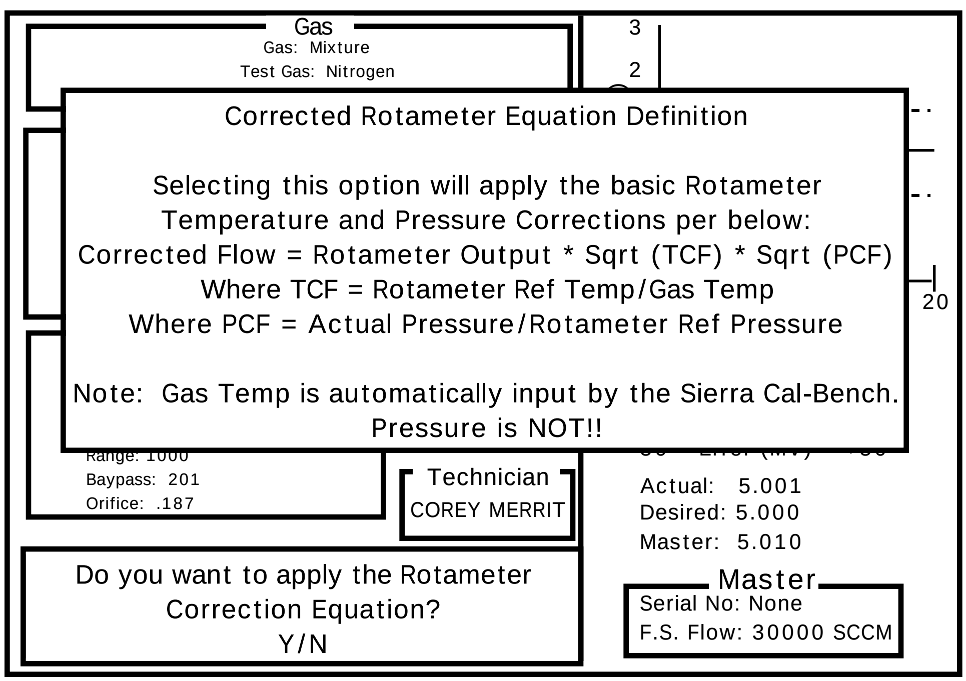
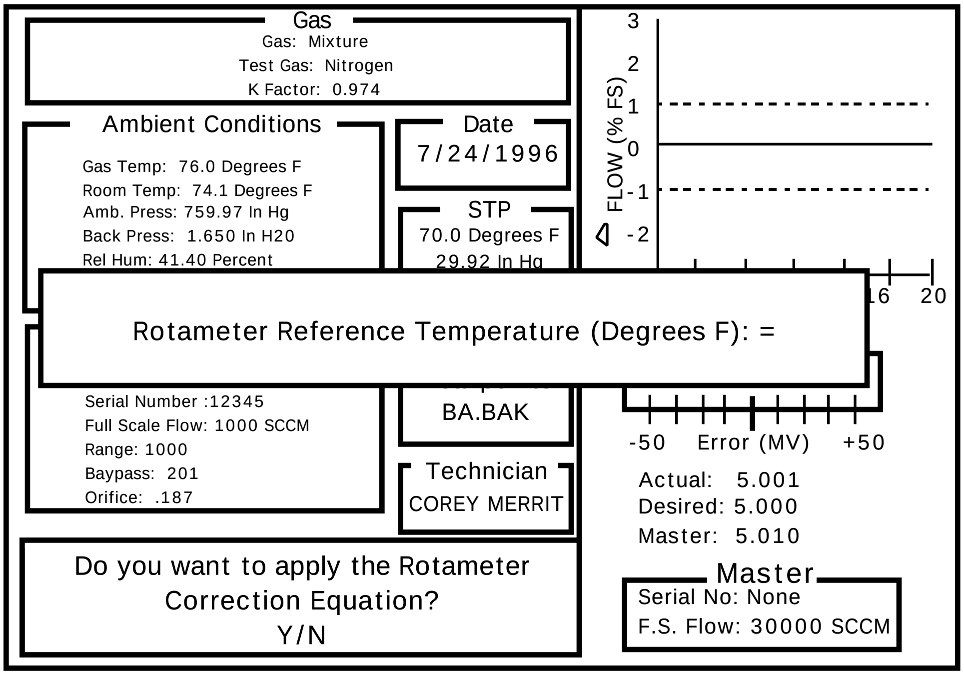


Figure 3-4. Final Q.C. Device Set Up

Selecting **N)on-Electrical Output Device** will open the window displaying the Connected Rotameter Equation Definition.



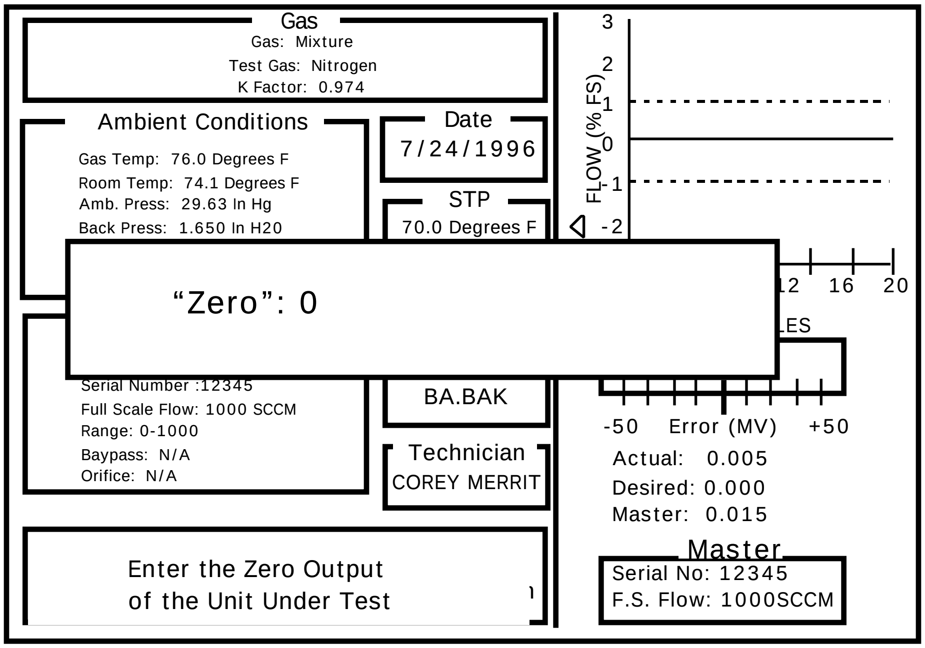
The Dialog Window will ask you if you want to apply the Equation. Press N for No or Y for Yes. If Yes, enter the reference temperature and pressure for the rotameter.



Next, the Dialog Window instructs you to set the switch positions on the Control Box Assembly:

Place Auto/Manual Switches in the AUTO mode
ENTER to Continue ESCape

Enter the zero output and the full scale output of the Device under Test as shown on the display:



After giving you the option of changing the stabilization time, the Dialog Window will show:

Flow XXX.XX SCCM (25%) using SMALL Tube
C)hange T)ube ENTER to continue ESCape

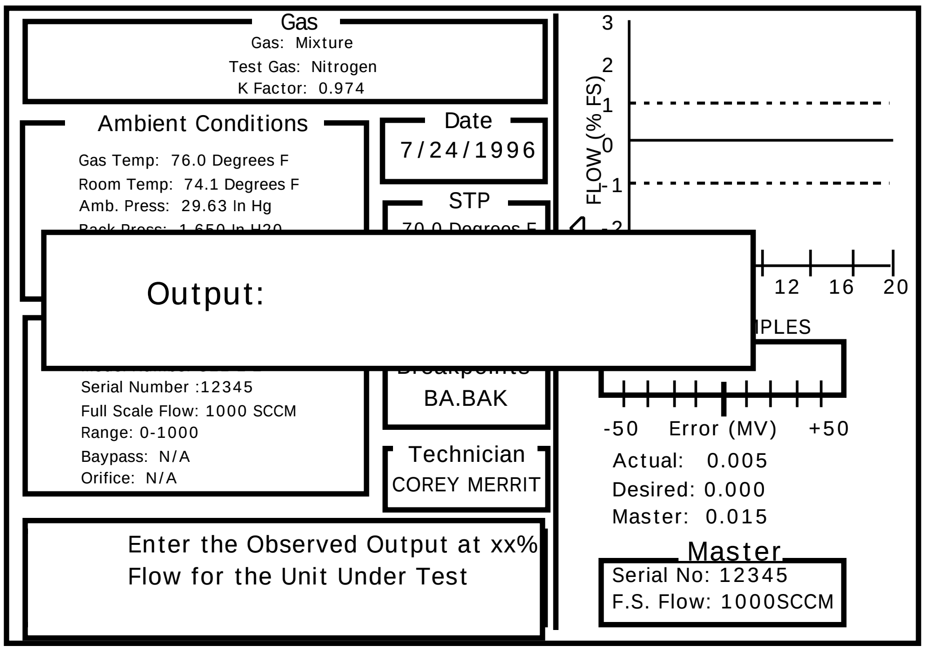
The flow rate is based on the full scale output of the Device Under Test and the first breakpoint listed in the Breakpoint file. Press C)hange to manually select the flow rate to be generated. The program will then command the Master mass flow controller to deliver a specified flow rate. This flow rate will depend upon the full scale range of the Device Under Test and the Breakpoint file used. The program will display the actual flow during the test in the command window:

Current Sample	Cumulative Flow
XXX.XX	XXX.XX

At the end of the test, the window on the main screen will display:

```
(25%) FLOW:  249.059 SCCM
R)un Again    ENTER to Accept    ESCape
```

During the test, the operator must observe flow rate reading from the Device Under Test. At the end of the test, the program will instruct the operator to input the indicated value from the Device Under Test, as shown in the following screen:



Enter the observed flow as indicated in the main window in the display screen and press ENTER to continue. After completion of an individual test, the program proceeds to deliver the flow as established by the next breakpoint.

When all breakpoints are completed, the program will then give you the opportunity to:

A)dd Comments   D)one

Pressing A)dd permits you to insert and review three lines of comments; pressing D)one proceeds to the next step which deals with the records.

Manual Transfer Standard

The Manual Transfer Standard mode is used for calibration with a secondary standard. The output from the secondary standard must be a 0-5 VDC linear signal. This may occur when you want to calibrate a mass flow meter controller that is outside the range of the Cal-Bench™ system.

This mode requires the use of a Master mass flow controller that is located in series with the device being calibrated. Manual Transfer calibration is nearly identical to the function of the Generate mode except that the flow rate is measured by the Master flow controller rather than the Cal-Bench tubes.

Make sure that the full scale range of the Device Under Test is equal to or less than the full scale range of the Master.

Caution

The Cal-Bench system must not be connected to the gas line in the Manual Transfer Standard mode. Disconnect any incoming gas flow before using Manual Transfer Standard mode.

Select "Manual Transfer Standard" from the main selection display screen and ensure that all information on the screen is correct.

The Dialog Window will then direct you to:

Place the Auto/Manual Switches in the AUTO mode ENTER to Continue ESCape

Check the switch position on the Dual Channel System Electronics Box and press enter to proceed. The following instructions will appear in the Dialog Window:

Turn Off Gas and Monitor Zero ENTER to Continue ESCape

and:

Turn On Gas and Adjust for Full Scale ENTER to Start Flow ESCape

Using the on-screen voltmeter, adjust the zero and full scale outputs of the Device Under Test when the appropriate prompts are displayed in the Dialog Window.

Using the selected Breakpoint file and the full range of the Device Under Test, the Cal-Bench will use the Master mass flow controller to deliver the required flow rate. The command window will display:

```
FLOW:  XXX (25%) Using Master Meter
C)hange Flow Rate ENTER to Continue  ESCape
```

Use C)hange to manually enter the flow rate to be delivered from the Master meter or ENTER to proceed with the test. The Cal-Bench system will give the Master mass flow controller the correct setpoint to deliver the required gas flow rate. The Dialog Window will display:

```
Adjust Unit Under Test and Hit ENTER
ESCape
```

The on-screen voltmeter will be activated. Adjust the meter being calibrated so that the Actual output voltage matches the Desired voltage. When these values match, press ENTER. The program will progress to the next value in the Breakpoint file. After completing the calibration at all breakpoints, the data may be reviewed. (See Appendix A for additional Breakpoint file information.)

Time Response

The Time Response function of the program permits you to display the response time of a mass flow controller. The flow controller must be connected to Channel 2 of the Control Box Assembly. Selecting the response time of a mass flow controller gives you the following default instructions in the Dialog Window:

```
Mass Flow Controller at 100% for 5 seconds
U)nit   T)ime   P)ercent   ENTER to Run   ESCape
```

U)nit cycles between using Mass Flow Meter, Mass Flow Controller and Semi Standard Test. Semi Standard test requires an optional LFE and pressure transducer. Testing the time response of a mass flow meter requires an optional valve assembly. Hardware for both Semi Standards test and testing a mass flow meter are available from Sierra Instruments.

T)ime selects the number of seconds to sample over. This is selectable between 1 and 60 seconds. P)ercent is the percentage of full scale (1 to 100) to test.

The test conditions in the command window will be updated as you change the information for U)nit, T)ime or P)ercent. When the test conditions are correct, press ENTER to perform the test. After completion of the test, the response curve will be displayed on the screen.

You can either P)rint the curve as a permanent record, press ENTER to run the test again or ESCape to the Main Menu. The response time test utilizes the 0-5 VDC output from the mass flow meter/controller.

Records

The Cal-Bench™ software program provides a database for storage and retrieval of the Calibration Records. The records are saved in a separate sub-directory titled by the serial number of the Device Under Test. If you are not familiar with handling of sub-directories, consult the DOS manual.

The calibration records can be saved during the Final Q.C. Test mode.

At the completion of the Final Q.C. Calibration Test, or by selecting "R" from the main menu screen, the following will be displayed in the command window:

```
RECORDS:   G)et   S)ave   D)elete
V)iew   P)rint   F)it Curve   ESCape
```

G)et will retrieve existing records in the data base;

S)ave will ask for a filename and then save the data just obtained;

V)iew will display the calibration data;

D)elete will permit you to delete an existing record;

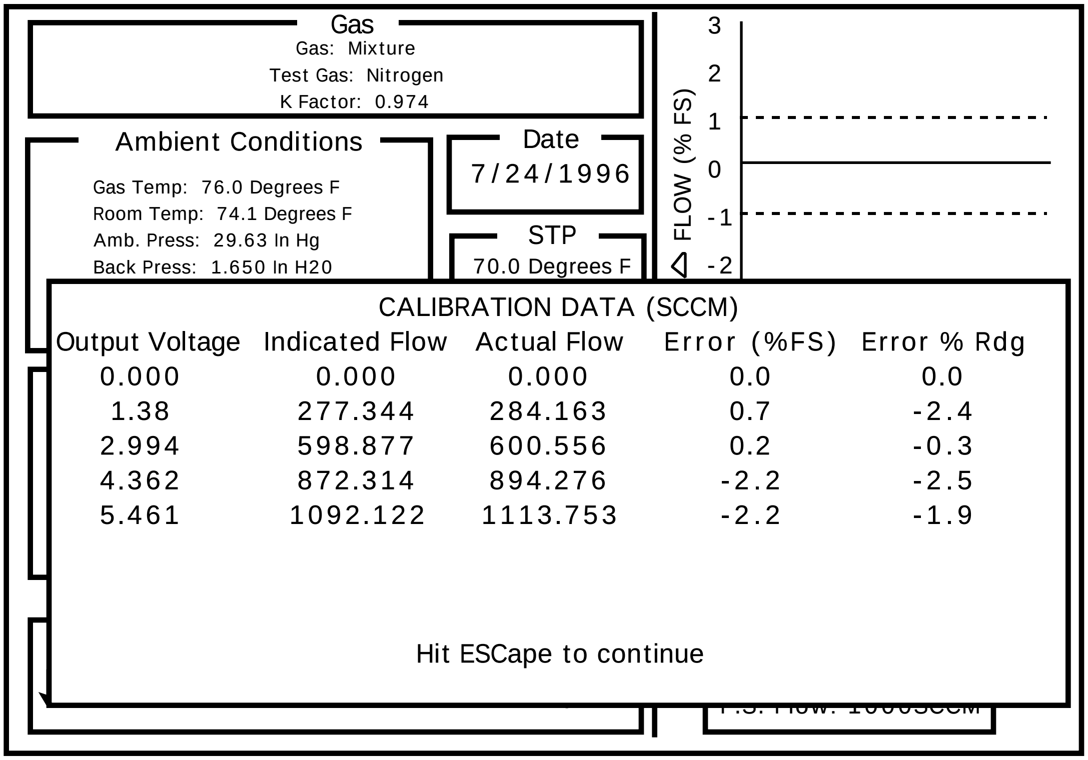
P)rint will print the active data in the report form and provide you with the transfer functions of the curve.

The printout can be configured for your specific needs in record keeping. The report, Configuration File, allows you to include or exclude specific data and change titles for the different blocks of data. See Report.CFG file in Appendix A. You can customize your report through the Custom.CFG file to include pertinent data to fulfill your quality assurance procedures. See Custom.CFG file in Appendix A.

F)it Curve will draw a curve of the data. A copy of the curve can be printed;

ESCape will continue;

V)iewing the data will display the following screen:



Output Voltage	Indicated Flow	Actual Flow	Error (%FS)	Error % Rdg
0.000	0.000	0.000	0.0	0.0
1.38	277.344	284.163	0.7	-2.4
2.994	598.877	600.556	0.2	-0.3
4.362	872.314	894.276	-2.2	-2.5
5.461	1092.122	1113.753	-2.2	-1.9

P)rint will print out the record in a format consistent with ANSI/NCSL Z540 and ISO/IEC Guide 25 reporting requirements.

Press P to print. Dialog window will show:

Hit F to print 4-20 mA Calibration Report Hit Enter to print Standard 0-5 VDC Report

Pressing F will print the Calibration Data as current over a range of 4-20 mA.

Pressing ENTER will print Calibration Data in 0-5 VDC format. Dialog window will show:

Hit D to add Due Date to Calibration Report Hit Enter to skip Due Date

Fill in Calibration Due Date if D is selected. Select E to edit Due Date or P to continue.

Dialog window will show:

Hit C to add CUSTOM data print out per CUSTOM.CFG file ESCape

Press C to customize the printout with specific data as stored in the Custom.CFG file.

ESCape will continue with printing the report without adding any of the customized data.

All records are stored in their own sub-directory using the serial number of the device being calibrated. As previously indicated, the serial number can not be longer than 6 characters.

When you want to G)et, S)ave or D)elete a record, the screen will display the names of the serial number sub-directories listed on the disk. Select the calibration records for that device by entering the appropriate information. The next screen will then display the individual calibration records of the specified device. Enter the name of the existing file to G)et or D)elete or enter the name of the file to be S)aved. The files are saved under standard DOS format. Make sure there are no spaces or illegal characters. Name length is limited by DOS to 8 characters plus a extension of three characters.

P)rint will print out the record in a format consistent with ANSI/NCSL Z540 and ISO/IEC Guide 25 reporting requirements. See previous page for P)rint. A copy of this form is included in Appendix A.

F)it Curve will display a graph of the calibration data. A copy of the graph can be printed. The curve will give insight on the shape of the curve; it is not an acceptable calibration curve per ANSI/NCSL Z540 and ISO/IEC Guide 25.

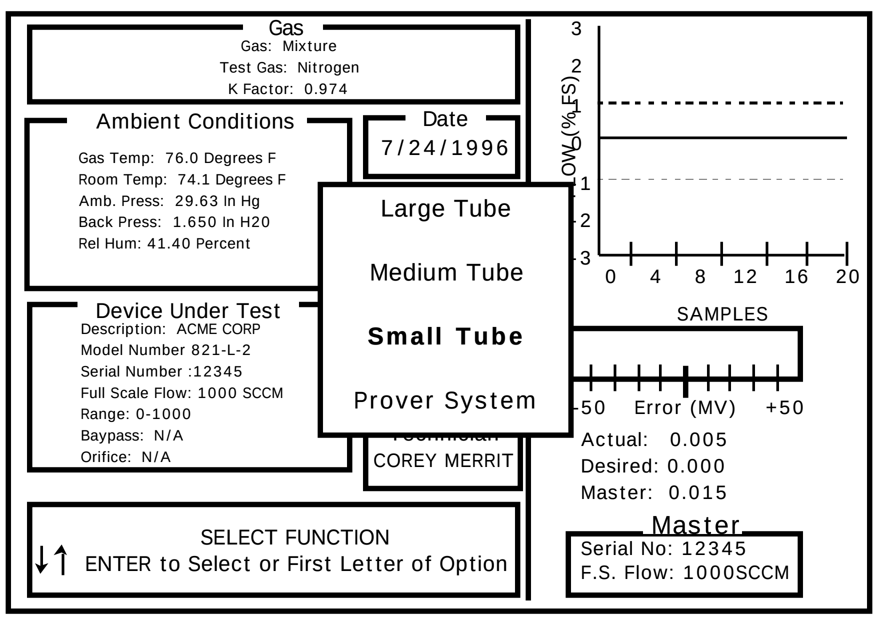
Verify Sonar Calibration

The sonar system used in the Cal-Bench™ system is an extremely accurate and repeatable method of measurement. The principle of operation of the Cal-Bench utilizes the measurement in the relative change in position of the piston over time. The Cal-Bench system has the ability to resolve the position of the piston with a resolution of 0.006 inches. This is obtained at any pressure or temperature (within the normal operating specifications of the Cal- Bench); the calculations of the speed of sound used in the program incorporate the actual pressure, relative humidity and temperature of the room where the Cal-Bench system is located.

The software has the ability to verify the readings made by the sonar transducer. To accurately verify the sonar transducer requires use of a very accurate measuring device such as a cathetometer or laser interferometer. Also the use of a laser interferometer will eliminate any parallax error due to possible distortion caused by looking through the glass tube which has a 1.4 index of refraction. The exact method of verifying the Sonar Calibration will be up to the individual user.

To verify the Sonar Calibration make the appropriate selection from the main menu. Press ENTER to proceed.

Select the tube to be checked as shown on the following screen:



Next enter all relevant information for G)as, D)evice or O)ther. Press ENTER to continue.

Select the units of measurement of:

Select Measurement Units I)nches C)entimeters ESCape

The Dialog Window will next display:

ZERO POSITION DISTANCE Hit ENTER When Piston is at Bottom ESCape

Make sure that the piston is located at the bottom of the tube and press ENTER to confirm.

Enter the “zero” value read on the measuring device at the top of the piston. From your measurement system, enter the distance value measured at the top of the piston. The program will then make its own readings of this distance and display the Average Deviation in the distance measurements. The Average Deviation should be no more than 0.5. Normal readings are usually less than 0.45.

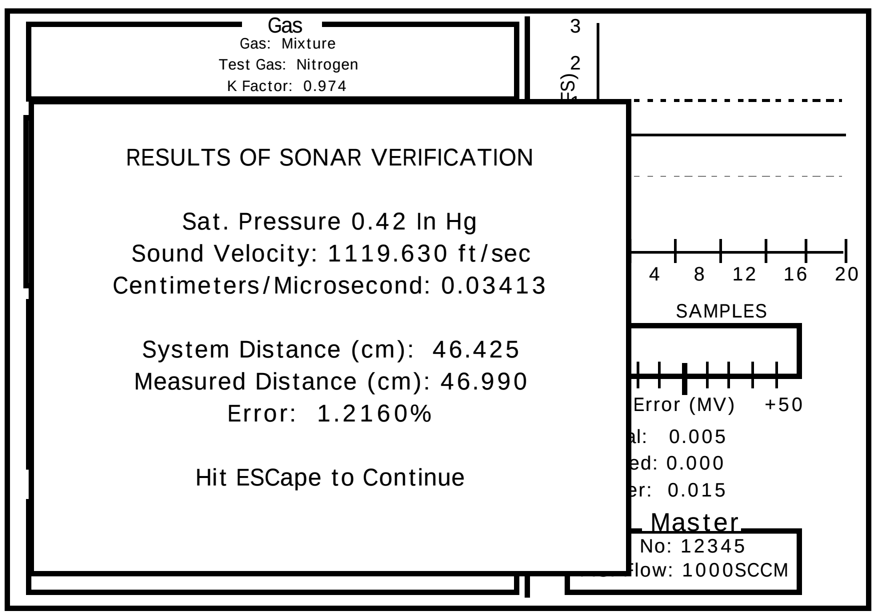
Next determine the top position distance. The Dialog Window will display:

TOP POSITION DISTANCE Put Piston about 22 inches above “zero” and Hit Enter

Manually turn on the gas and let the piston move until it is approximately 22 inches above the “zero” position and shut off the gas. Allow the piston to come to "equilibrium" for three minutes prior to proceeding. The Dialog Window will then direct you to measure the top of the piston. The Dialog Window will display:

> Enter the Value Read on the Measuring
> Device at the Top of the Piston

The program will make multiple readings of the distance the sonar measures to the top of the piston and display the average deviation. If the standard deviation is greater than 0.5 the piston is moving during the test. Recheck the system for leaks and ensure that you have waited an adequate stabilization period before performing the test. The program will display the results of the Sonar Verification as indicated below:



These readings should be within 0.5%. If the readings are not within this limit, recheck your measurement system, the ambient conditions in the room and rerun the test.

The sonar transceiver determines the distance by timing the "flight time" of the sonar pulse. The speed of sound is affected by ambient temperature, ambient pressure and relative humidity. Possible causes for error are:

1. The Ambient Temperature read or entered is not correct. Check this input.
2. The Ambient Pressure read or entered is not correct. Check this input.
3. The Ambient Relative Humidity read or entered is not correct. Check this input.
4. The 1 MHz clock timer is not functioning properly. See Chapter 4 for procedures on checking the clock timer.

The sonar verification performs a functional test on multiple variables utilized in the systems. Performing this test allows you to check overall system performance.

D/A and A/D Adjust

The Cal-Bench Software permits you to easily adjust the A/D and D/A converters.

The Command Screen will display:

```
Outputting X.XX Volts
C)hange voltage  ESCape
```

Use C)hange voltage to select any desired voltage between 0 and 5 VDC. The voltmeter on the main screen will display the output from the Device Under Test and the Master MFC. Press ESCape when done.

Actual indicates the output voltage of the Device Under Test. The arrow is a visual display of the mv difference between the actual voltage read and the desired voltage. Master indicates the output voltage for the Master MFC. Desired is the setpoint command to the Device Under Test and the Master MFC.

See the A/D and D/A instructions in Chapter 4.

Leak Test

This portion of the Cal-Bench software program is used to check the leak integrity of the piston, the piping system up to your shut-off valve and the Cal-Bench seals. It is recommended that this test be performed on a daily basis, preferably at the start of each day.

The principle of this test is to position the piston mid-way up the tube and shut off the gas. The sonar makes multiple measurements of the position of the piston in the tube. Any increase in the distance measured (piston falling) will indicate a leak in the system; any decrease in the distance measured (piston rising) will indicate that gas is still entering the system from a leaky valve or expansion of the gas after being injected into the tube under test.

Select the Leak Test option from the main selection menu and then choose the tube to test.

```
Large Tube
Medium Tube
Small Tube
Prover
```

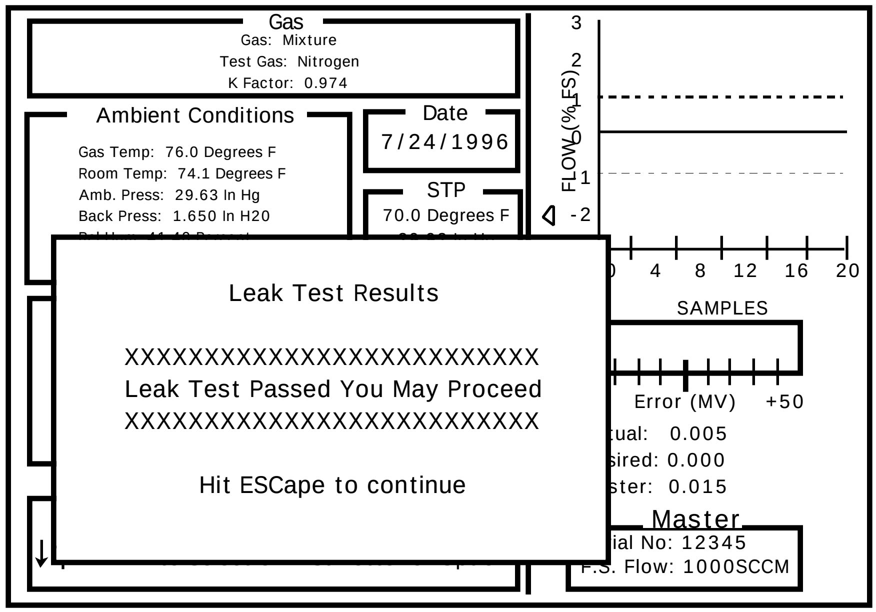
All three tubes should be tested to make sure the seal between the piston and the tube and the seal between the tube and the Cal-Bench system is not compromised. After the tube is selected, the Dialog Window will display:

```
Leak Test Procedure
Raise Piston 15"    A)utomatic    M)anual    ESCape
```

Turn on the gas and raise the pistons approximately 15". Then shut off the valve. Press either A)utomatic, M)anual or ESCape.

The program will take and display continuous readings of the position of the piston. The number displayed is the actual flight time of the sonar pulse from the transceiver to the top of the piston and returned to the transceiver. An increase in the flight time will indicate that the piston is falling due to a leak in the system. The readings should not change by more than 3 counts in thirty seconds.

In the A)utomatic mode, the test will proceed for 30 seconds and then compare the initial and current readings. If the change in position of the pistons is less than 3 counts in 30 seconds, the test passes over the following screen display:



In the M)anual mode, the test continues until the ESCape key is pressed. The operator must time the length of the test and determine if an acceptable result is obtained.

The Automatic Leak Test procedure simplifies the test and provides you with a pass/fail result.

System Information

Selecting System Information displays the System Information screen. This provides you with all information relative to the Cal-Bench system you have purchased. In locations with more than one Cal-Bench, it is important to ensure that your tube serial numbers and constants match your actual tubes and supplied calibration data.

Bell Prover Operation

The software operation of the bell prover is identical to operating the system with the Cal-Bench cabinet with minor changes. Initial set-up of the software is the same as if you were using the glass tubes but selecting the bell prover as your flow standard. Flow is manually diverted to the bell prover if your system has a cabinet with the glass calibration tubes.

Caution

Monitor system pressure to avoid excessive flow into the Cal-Bench cabinet. Blown mercury seals could result.

Calibrate Mode

Select Calibrate from the basic display screen. Set up the calibration parameters for Ambient Conditions, Device Under Test, Gas, STP and Date as described in the previous sections of this chapter.

Open the top ball valve and close the bottom ball valve on the bell prover. Divert flow to the bell prover.

Press T)ube, to select the bell prover. The Tube Select window will open in the center of the screen. If your system has a second bell prover, the window will have the three glass tubes, Prover and Qprover to select from. Place the highlighted bar over Prover (or Qprover). Press ENTER to select or simply press p (or q).

Large Tube

Medium Tube

Small Tube

[redacted]

QProver

Press ENTER to initiate flow measurement. The display will update the information in the Ambient Conditions window. If your system has a cabinet, the solenoid vent valve in the cabinet will engage. The dialog box at the bottom of the screen will briefly display “Waiting for Piston to Start...” Open the bottom ball valve and close the top ball valve on the bell prover. As flow is measured the dialog box at the bottom of the screen will display the current and the cumulative flow as the bell rises.

Press the Space Bar at any time to stop the flow measurement or let the bell continue to rise and the software will detect the top of the run and stop measuring flow. A window will open on the display showing the flow rate and output voltages. Open the top ball valve and lower the bell.

Generate Mode

Select Generate from the basic display screen. Set up the Generate calibration parameters for Ambient Condition, Device Under Test, Gas, STP, Date, Breakpoints, Master Serial Number and Master Full Scale Flow as described earlier in this chapter.

Set up the master and DUT as described earlier in this chapter. The software will select the appropriate size tube or bell prover according to the flow rate determined by the Breakpoint file and the full scale flow to the DUT. When the software selects the bell prover, manually divert the flow to the bell prover.

Continue with the software until the Dialog Window displays:

```
Flow:  XXXX.XX      SCCM (25%) Using Prover

C)hange     T)ube     ENTER to Continue     ESCape
```

Press ENTER to initiate generating the first breakpoint. The software will generate the flow rate governed by the breakpoint through the master. The software will generate the flow within ±2% of the desired flow rate. This process may take several attempts. The software will select the bell prover when the flow rate exceeds the flow capabilities of the glass tubes and is in the range of the bell prover. Open the bottom ball valve and close the top ball valve on the bell prover to begin measuring flow. Between each attempt to generate flow, allow the bell to lower by opening the top ball valve. Once the flow is set, the software will take a full run of the bell prover. Close the top ball valve. Let the bell rise until the software detects the top of the run and stops measuring flow. Open the top ball valve. Lower the bell. A window will open on the display showing the flow rate and output voltages.

Adjust the Device Under Test for the correct output voltage using the on-screen voltmeter. Press ENTER when done to go on to the next breakpoint.

The program will continue in this manner until all of the calibration points specified in the Breakpoint File are completed.

Final QC Calibration

Select Final Q.C. Calibration from the basic display screen. Set up the Final Q.C. Calibration parameters for Ambient Conditions, Device Under Test, Gas, STP, Date, Breakpoints, Master Serial Number and Master Full Scale Flow as described earlier.

Set up the master and DUT as described earlier in this chapter. The system software will select the appropriate size tube or bell prover according to the flow rate determined by the Breakpoint File and the full scale flow of the Device Under Test.

When the software selects the bell prover, divert flow to the prover.

Continue with the software until the Dialog Window displays:

```
R)egular        A)utomatic

N)on-Electrical Output Device        ESCape
```

Press R, (R)egular) to select the regular mode which permits you to approve or re-run each individual test. Each test flow rate will be determined by the percentages in the Breakpoint file selected. Continue with the software until the Dialog Window displays:

```
Flow:   XXXX.XX        SCCM (25%) Using Prover

C)hange     T)ube     ENTER to Continue     ESCape
```

The software will select the bell prover when the flow rate exceeds the flow capabilities of the glass tubes and is in the range of the bell prover. Press ENTER to begin measuring flow. Open the bottom ball valve and close the top ball valve on the prover. The software will run the bell all the way to the top or you may press the space bar to stop the flow measurement. Open the top ball valve and close the bottom ball valve at the end of the flow measurement.

At the end of the run, a window will open on the screen to display the flow rate of the test run and corresponding voltage for the flow rate displayed.

```
(25%) Flow:    XXXX.XX SCCM

Output Should be:   1.250 VDC or 8.000 mA

R)un Again          ENTER to Accept          ESCape
```

The voltmeter display will show the actual output voltages of the Device Under Test. Press ENTER to accept the test results and continue to the next breakpoint and flow measurement.

The program will continue in this manner until all of the calibration points specified in the Breakpoint File are completed.

Final Q.C. Calibration may be run in the automatic mode with the bell prover. Press A, (A)utomatic) to run each breakpoint without interruption. When the software selects the bell prover, divert the flow to the prover.

The software will initiate measuring flow for each breakpoint. When the dialog box displays "Waiting for piston to start....," open the bottom ball valve and close the top ball valve on the bell prover. At the end of the test run, open the top ball valve and lower the bell. The software will proceed to the next breakpoint. Continue in this manner until all of the points in the Breakpoint Files have been run.

Verify Sonar Calibration

Bell provers use a linear displacement encoder to measure the ascent of the bell. Verify Sonar Calibration allows the user to verify the readings made by the linear encoder. To accurately verify the linear encoder, you will need a very accurate means of measuring distances over a range of 0 to 24 inches. You will be measuring the displacement of the bell from a "zero" position to a "top" position, (bell raised approximately 22 inches.)

The exact method of measurement used is up to the individual user. For accurate readings, leak test the bell prover before you proceed with Verify Sonar Calibration.

One method to verify the sonar calibration is to place a certified metal rule along the pulley post. Fix the rule to the post with masking tape. Fix a pointer to the counterweight next to the rule so the pointer is across the marks on the rule. The pointer must not touch the rule but must be close enough to eliminate parallax.

Select Verify Sonar Calibration from the basic display screen. Set up the Verify Sonar Calibration parameters for Ambient Conditions, Device Under Test, Gas, STP, Date, Breakpoints, Master Serial Number and Master Full Scale Flow as described earlier.

Press T)ube to select the bell prover. Select the units of measurement, inches or centimeters.

Position the bell to the bottom, “zero” position. Press ENTER when the bell is in place. Enter the “zero” in the units chosen above as the pointer indicates on the rule. Press ENTER. The software will make multiple readings of the distance the encoder measures and displays the average deviation. The average deviation should be no more than 0.50. Normal readings are less than 0.45.

Flow air into the bell prover to position the bell to the ”top” position approximately 22 inches above “zero.” Shut off the flow by closing the ball valves on the bell prover. Press ENTER. Enter the “top” in the units chosen above as the pointer indicates on the rule. Press ENTER. If the average deviation is greater than 0.50, the bell is moving during the test. Re-check the system for leaks and make sure you have waited an adequate stabilization period before performing the test again.

A window will open on the screen displaying the results of the test. The percent error displayed must be 0.5% or less. If the results are not within this limit, re-check for leaks, update ambient conditions, re-check your measurement system and re-run the test.

Leak Test

Leak Test gives you the ability to test the leak integrity of the bell prover and the piping system up to your shut-off valves.

The principle of this test is to position the bell approximately 15 inches above the “zero” position and shut off the air flow to the bell prover by closing the prover ball valves. The software will make multiple measurements of the linear encoder.

Any indication of the increase of the distance measured (bell falling) will indicate a leak in the system.

Any decrease of the distance measured (bell rising) will indicate that air is entering the system from a leaky valve.

Select Leak Test from the basic display screen. Press T)ube to select the bell prover. Raise the bell up approximately 15 inches.

Select A)utomatic for a 30 second test or select M)anual for a continuous test until the ESCape key is pressed.

The software will display a number relative to the distance the encoder measures over the period of the test. The number displayed should not increase or decrease more than three counts to successfully pass the leak test.

When the test is terminated, either automatically or manually, the software will display the results of the test:

```
- LEAK TEST RESULTS -
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Leak Test Passed     You May Proceed
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Hit  ESCape  to Continue
```

If leak test fails, re-check the system for leaks and re-run the test.

Chapter 4 Equipment Schedules

This chapter covers the Cal-Bench™ equipment schedules. Equipment schedules are divided into the categories of Certification and Maintenance. The Certification Schedule is required to maintain the calibration integrity of your Cal-Bench system. The Maintenance Schedule covers procedures necessary to keep your system in good operating condition. Perform the following tasks:

Daily

- Leak Test Tubes... page 3-45
- Leak Test Bell Prover Option .... page 3-51

Monthly

- Clean Small Tube....................................page 4-2 & 4-3

Every Six Months

Maintenance Schedule

- Clean Medium Tube.............................. pages 4-2 & 4-11

Certification Schedule

- Sonar Alignment... page 4-24
- Analog to Digital and Digital to Analog Converters.... page 4-27
- System Clock Calibration .... page 4-32

Annual

Maintenance Schedule

- Clean Large Tube................................. pages 4-2 & 4-18
- Calibrate 902 Control Box Assembly.................... page 4-33
- Calibrate Master Mass Flow Controller
  (see Mass Flow Controller Instruction Manual for procedure)

Certification Schedule

- Gas Temperature Probe Calibration...................... page 4-35
- Back Pressure Transducer Calibration................... page 4-39
- Ambient Pressure Auto Input Calibration .... page 4-43
- Ambient Temperature and Relative Humidity Cal...... page 4-45

Every Three Years

Certification Schedule

Tube Maintenance Procedures

In order to maintain Cal-Bench system performance, tube maintenance is required on a regular basis. Cleaning the tubes with ammonia-free glass cleaner and treating the small tube with Anstac 2-M on a regular cycle will ensure repeatable and trouble free performance.

If the Cal-Bench system is used on a regular basis, day in and day out, the following cleaning cycle should be followed:

- Small Tube: Clean every month
- Medium tube: Clean every six months
- Large Tube: Clean every twelve months

The small tube should always be treated with Anstac 2-M. Anstac 2-M cannot be purchased through Sierra Instruments, Inc. For information on obtaining Anstac 2-M reference the following:

Solution: **Anstac 2-M22**
CDC International, Inc.
Portsmouth Road
Amesbury, MA 01913

The following materials are required for tube cleaning:

1. One 4’ x 1/4” wooden dowel
2. Box of small Kimwipes (Order No: 34155, 4.5” x 8.5”)
3. Box of large Kimwipes (Order No: 34256, 15” x 17”)
4. Ammonia-free glass cleaner
5. Anstac 2-M (for small tube only)
6. 50 MHz oscilloscope (with two channels, A&B)
7. 14 pin I.C. clip
8. Large bag of powder-free latex gloves
9. Mercury vapor respirators
10. Mercury Spill Control Station (with hand held vacuum pump)
11. Mercury disposal container with plastic bags for dirty wipes
12. Mercury container for dirty mercury
13. Phillips screwdriver (#2)
14. 1’ x 1’ plastic tray with 2” tall sides
15. Small acid brush
16. General purpose o-ring lubricant
17. 2 lbs. of Specially Refined or Triple Distilled Mercury

Small Tube Cleaning Procedure

Perform this procedure every month.

Warning

Mercury and Mercury Vapors are toxic! The utmost precaution and care must be taken while transporting and handling mercury. Failure to take appropriate measures when handling mercury could result in hazardous exposure of personnel.

1. Put on a pair of latex gloves, goggles (for eye protection) and mercury vapor respirator.
2. Remove the black knobs that secure the hood and flip the hood back.
3. Select Calibrate from the main operational mode menu. Select the small tube. Remove the hold down bracket that secures the small sonar transducer in place.

Note

It does not help to mark the original position of the sonar with a marker. Later in the sonar alignment procedure we will thoroughly review how to properly re-align the sonar transducer.

1. If the small piston was over pressurized and mercury is present when you remove the sonar, firmly tap the sonar with a side-to-side motion. Mercury should come out of the sonar transducer. Usually, there is a funnel-shaped tube extender located in the sonar transducer. Remove the extender and tap the sonar against the PVC top tube retainer again to remove all traces of mercury.
2. Re-install the tube extender in the small sonar transducer.

Note

When re-installing the tube extender in the sonar transceiver always install it with the large ID up towards to the sonar and the small ID down toward the top of the small tube.

1. Contain any mercury that was retrieved from the sonar into a small puddle. Vacuum it using the small hand held pump supplied in the Mercury Spill Control Station.
2. Place the vacuum pump on the small plastic tray when mercury recovery is complete.

3. Remove the Plexiglas window from the front of the cabinet.

4. Loosen the threaded ring nut securing the top of the small tube and pull it down about one foot.

5. Carefully turn the small tube clockwise and slowly pull up on the tube for a distance of approximately one foot. The piston should remain in the cabinet or fall out as you elevate the tube. To avoid damage, use your small acid brush to gently push the piston and target toward the cabinet back panel.

6. Pull back down on the small tube. The o-ring sealing the top of the tube should come down.

7. Elevate the small tube over its well a distance of about 5 inches.

8. Use the small acid brush to brush all mercury off of the base of the tube. Use a small Kimwipe to clean off mercury higher up outside of the tube. All visible mercury on the exterior of the small tube should be wiped off *inside* of the cabinet.

9. When the tube base is thoroughly wiped of mercury, remove the threaded ring nut and o-ring and place them on the plastic tray.

10. Carefully remove the small tube by pushing it up and out through the top of the cabinet.

Caution

Never try to pull the small tube out through the front of the cabinet. Tube damage could occur.

1. Lay the tube on a clean and level table top and verify that the tube will not roll off.

2. Remove your gloves and dispose of them in a mercury disposal container. Put on another pair of clean gloves.

3. Prep the wooden dowel by wrapping and rolling two small Kimwipes on one end of the dowel. Use masking tape to secure the wipes. (The goal is to make a long Q-Tip.)

4. Cover the end of the prepped dowel with two more small Kim-wipes. Make sure the Kimwipes cover the masking tape.

Caution

Be careful that masking tape is not exposed in the tube. If the tape adhesive adheres itself to the tube, the piston will jerk or become stuck in the tube.

1. Flood the tube with ammonia-free glass cleaner. Swish it around inside of the tube until the tube becomes saturated with the solution.

2. Drain the excess contaminated solution into the mercury disposal container.

3. Use the prepped dowel to thoroughly scrub the inside of the tube. Scrub the inside of the tube for approximately one minute.

4. Remove the dowel from the tube. Replace the two taped small Kimwipes with clean dry wipes.

5. Run the dowel through the inside of the tube with a rotating motion to dry the inside of the tube.

6. Remove the dowel from the tube and replace the two wipes again.

7. Run the dowel through the inside of the tube once again to thoroughly dry the inside of the tube.

8. Remove the dowel from the tube and wipe off the outside of the tube. Make sure it's clean and dry.

9. Remove all wipes from the dowel and re-prep the dowel with clean wipes as described in steps 18 and 19.

10. Soak the prepped end of the dowel with the Anstac 2-M.

11. Run the saturated wipes through the inside of the tube again and coat the inside of the tube evenly with the Anstac. Remove the dowel from the tube, soak the same wipes again and run the dowel through the tube a second time.

Note

Both times the dowel should be run up and down the full length of the tube in a rotating motion to evenly coat the inside of the tube.

1. Remove the dowel from the tube and let the tube cure for five minutes. Use a stop watch or second hand if available.

2. While the small tube is curing, clean the small piston.

3. The small piston should still be in the cabinet. Remove all of the mercury from the piston while it's still in the cabinet. It is effective to hold the piston and shake the mercury off.

Caution

DO NOT tap the piston against any part of the cabinet. This could damage the piston. Carefully brush off any excess mercury that will not come off by shaking the piston.

1. Dampen a few small Kimwipes with the cleaner and gently clean the piston.

Caution

Do not soak the piston.

1. When the piston is clean, dry thoroughly using only Kimwipes.
2. Lightly dampen a Kimwipe with Anstac 2-M. Apply a light film to the piston.
3. If five minutes have elapsed, soak the prepped end of the wooden dowel again with the Anstac 2-M. Run the dowel through the tube and coat it evenly.
4. Remove the dowel and replace all of the Kimwipes on the end of the dowel. Replace the taped wipes with clean wipes also.
5. After re-prepping the dowel end, run the dowel through the tube to dry the inside of the tube.

Caution

Do not blow air or nitrogen (N2) through the small tube.

1. Replace the two outside wipes again to finish thoroughly drying the inside of the tube.
2. Remove the dowel from the tube and dispose of all tape and wipes used to clean the tube and piston.
3. Lightly re-coat the small piston with Anstac 2-M and dry immediately.
4. When the tube and piston are clean and treated, contain all of the mercury that is not in the small tube well. Use the small acid brush to confine the mercury into a single puddle toward the rear of the cabinet. Use the vacuum pump in the Mercury Spill Control Station to vacuum the mercury.

5. When excess mercury is contained, replace the metal tip of the mercury hand pump with a red straw (similar to the red straw supplied with WD-40). Replacing the metal tip of the hose with the red straw also allows you access to the base of the mercury overflow cup for the small tube.

Caution

It is mandatory that you remove all mercury from the overflow cup to avoid un-repairable damage to the brass inlet block, rotary valve and solenoid valves.

1. To remove the mercury overflow from the base of the inlet block, insert the red straw down the air flow port of the small tube. Push the full length of the straw all the way down until it reaches bottom. Lower the mercury vacuum pump below the tip of the red straw.

2. There should now be mercury in the well of the small tube where the base of the tube is recessed.

Caution

It is strongly recommended that mercury in the well of the small tube also be vacuumed out to avoid splashing of mercury during tube installation.

1. Once all contaminated mercury has been contained and disposed of in the “dirty mercury container,” change your gloves.

2. After the glove change, insert the small tube from the top of the cabinet. When inserting the tube, slip the dry o-ring over the bottom of the tube. Roll it up the length of the tube before the tube reaches the bottom of the cabinet.

3. Slip the threaded ring nut over the base of the small tube and then recess the tube in its well.

4. Push down on the tube from the top of the cabinet and roll the o-ring up until about 3 inches from the bottom of the PVC tube retainer. Grease the o-ring extra-heavy. Use the threaded ring nut to push the o-ring up into the o-ring groove. As you push the o-ring into the groove, pull down on the tube so it’s not pushed up out of its well. Secure the threaded ring nut finger tight.

Caution

It is possible to break the tube by over-compressing the o-ring.

1. Change your gloves again.

2. Install the small piston by softly gripping the neck of the piston with a small pair of needle nose pliers. The groove in the piston should be positioned below the top of the tube, allowing the mercury seal to form around the piston.

3. Fill the piston column with the triple distilled or specially refined mercury. Use the supplied syringe to force the mercury down the piston's column. Once the mercury level has reached the top, remove the needle and place the metal sonar reflector on top of the piston.

Warning

When a syringe is loaded with mercury, NEVER point the needle downward when away from the Cal-Bench cabinet or a confined tray. Mercury will fall out of the syringe onto the floor contaminating your work area.

1. Release the piston. It should fall to the bottom of the tube. Use the mercury vacuum pump to contain any spilt mercury on the top plate.

2. Replace the sonar transducer over the tube and loosely fasten the sonar transducer with the hold down bracket.

3. Force mercury into the well of the small tube to seal the base of the tube. The syringe used to load the mercury into the piston can be used for sealing the tube also.

4. The level of the mercury in the well should be approximately 1/8" from the surface of the PVC tube retainer. If mercury stock is low, you may reuse contaminated mercury to seal the base of the tube.

Caution

Never use contaminated mercury to seal the piston. This could cause equipment damage.

1. Deposit any mercury left in the syringe to its container. If dirty or contaminated mercury was used, be sure to return the dirty mercury back to the "dirty mercury container."

Caution

Do not use the syringe that was used for dirty mercury with clean mercury.

1. Return all supplies to their proper location to eliminate any mercury accidents. Pour any mercury in the mercury vacuum pump into the "dirty mercury container." Return the container to its proper storage area.

2. Re-position the Plexiglas window in the cabinet.

3. Dispose of your gloves in the mercury disposal can or bag.

4. Turn off all power to the sonar box. Use a Phillips screwdriver to remove the front bezel from the sonar box and remove the blue top by sliding it out.

5. Follow the Sonar Adjustment/Calibration procedure on page 4-24 to guide you through oscilloscope hook-up settings.

Caution

Do not make any potentiometer adjustments without consulting the factory first. Adjustments to this circuit can affect sonar calibration. If you need assistance, call the factory: 1-800-866-0200.

1. The goal is to adjust the sonar transducer unit in the cabinet until you achieve a clean sonar signal.

Note

This alignment procedure is needed only for the small tube. (The I.D. of the other tubes are large enough that special attention to the sonar signal is not necessary.)

1. Disable the solenoid valves (toggle black vent switch on front panel of the Cal-Bench system to manual vent). Run Leak Test mode from the main menu. Observe the real time values displayed on the system and use the oscilloscope to help you focus the sonar. When a clean signal and system leak test values are consistent, secure the sonar transducer by tightening the bracket across the sonar.

Caution

Do not over-tighten the bracket. This could cause undesirable sonar alignment.

1. Insulation cushions the sonar transducer from the bracket. Tighten the bracket only a few turn with the Phillips screwdriver. The insulation should still appear spongy.

Note

If the sonar bracket that secures the sonar is over-tightened and the insulation becomes permanently over-compressed (flattened), the last reading that the system samples during a calibration can jump high or low causing the current reading to average higher or lower with a one percent of reading error or greater.

1. When the sonar transducer bracket is secured and the hood is closed, double check the signal on the scope and in the Leak Test mode. If the signal still looks healthy, exit the software to the root directory and power the system down. Remove the oscilloscope and re-assemble the sonar box enclosure.

2. When the system is powered up again there may be noticeable difference in the system values in the Leak Test mode. The cause of the lower reading is the absence of the load influenced by the oscilloscope.

3. Return all remaining equipment to storage.

4. Run Leak Test in automatic mode to raise the piston 15" up the length of the tube to check for any leaks. (The Cal-Bench Sonar box should indicate 1.8 for approximately 15.")

5. This completes the Small Tube Cleaning Procedure.

Medium Tube Cleaning Procedure

Perform this procedure every six months.

Warning

Mercury and Mercury Vapors are toxic! The utmost precaution and care must be taken while transporting and handling mercury. Failure to take appropriate measures when handling mercury could result in hazardous exposure of personnel.

1. Put on a pair of latex gloves, goggles (for eye protection) and mercury vapor respirator.

2. Remove the black knobs that secure the hood and flip the hood back.

3. Select Calibrate from the main operational mode menu. Select the medium tube. Remove hold down bracket that secures the medium sonar transducer in position and place the bracket in the hood.

4. If mercury is present when you remove the sonar, firmly tap the sonar with a side-to-side motion. Mercury should come out of the sonar transducer. When the mercury is removed, place the sonar in the hood.

Note

Unlike the small sonar transducer the medium sonar does not require a tube extender.

1. Remove the medium tube spacer and place it in the hood, out of the way. (If the spacer seems too difficult to remove by hand, use a screwdriver to twist the spacer off. Align the screwdriver with two holes, turn and pull at the same time.)

2. Contain any mercury that was retrieved from the sonar into a small puddle and vacuum it using the small hand held pump supplied in the Mercury Spill Control Station.

3. When mercury recovery is complete, place the vacuum pump on the small plastic tray.

4. Remove the Plexiglas window from the front of the cabinet.

5. Loosen the threaded ring nut securing the top of the medium tube and pull it down about one foot.

6. Turn the medium tube clockwise and slowly pull up on the tube for a distance of approximately one foot. The piston should remain at the base of the cabinet. Use your small acid brush to push the piston back toward the rear panel to avoid any damage to the piston during initial cleaning and removal of the tube.

7. Pull back down on the tube. The o-ring sealing the top of the tube should come down.

8. Raise the medium tube above its well a distance of about 5 inches.

9. Use the small acid brush to brush all mercury off of the base of the tube. If there is any mercury higher up outside of the tube wipe it off using a small Kimwipe. All visible mercury on the exterior of the medium tube should be wiped off inside of the cabinet. Use the small Kimwipes to remove excess mercury from the tube anywhere five inches above the base of the tube.

10. After the base of the tube has been thoroughly wiped of mercury, remove the threaded ring nut and o-ring and place them on the plastic tray.

11. Carefully remove the medium tube by pushing it up and out through the top of the cabinet.

Caution

Never try to pull the medium tube out through the front of the cabinet. Tube damage could occur.

1. Lay the tube on a clean and level table top and verify that the tube will not roll off.

2. Remove your gloves and dispose of them in a mercury container. Put on another pair of clean gloves.

3. Prep the wooden dowel by wrapping and rolling two small Kimwipes on one end of the dowel and securing the wipes with masking tape. (The goal is to make a long Q-Tip.)

4. Cover the end of the prepped dowel with two more small Kimwipes and be sure to cover the masking tape. Build up the wipes until the dowel can effectively can scrub the inside of the tube. Do not layer too many wipes on the dowel. The dowel must be able to easily slip into the medium tube.

Caution

Be careful that masking tape is not exposed in the tube. If the tape adhesive adheres itself to the tube, the piston will jerk or become stuck in the tube.

1. Flood the tube with ammonia-free glass cleaner and swish it around inside of the tube until the tube becomes saturated with the solution.

2. Drain the excess contaminated solution into the mercury disposal container.

3. Use the prepped dowel to thoroughly scrub inside of the tube. Scrub the inside tube for approximately one minute.

4. Remove the dowel from the tube. Replace the untaped large Kimwipes with clean dry wipes. Again, build up the wipes until the dowel can effectively scrub the inside of the tube.

5. Run the dowel through the inside of the tube with a rotating motion to dry the inside of the tube.

6. Remove the dowel from the tube and replace the two wipes again.

7. Run the dowel through the inside of the tube once again to thoroughly dry the inside of the tube.

8. Remove the dowel from the tube and wipe off the outside of the tube so it is also clean and dry.

Note

Treating the medium and large tubes with Anstac 2-M is not necessary unless static discharge becomes a problem If static discharge becomes a problem, re-clean the tube and piston and reference “Cleaning the Small Tube Procedure.”

1. The medium piston should still be in the cabinet. Remove all of the mercury from the piston while it's still in the cabinet. It is effective to hold the piston and shake the mercury off of it.

Caution

DO NOT tap the piston against any part of the cabinet. This could damage the piston. Carefully brush off any excess mercury that will not come off by shaking the piston.

1. Dampen a few small Kimwipes with the cleaner and gently clean the piston.

Caution

Do not soak the piston.

1. When the piston is clean, dry thoroughly using only Kimwipes.

2. Now that the tube and piston are clean, contain all of the mercury that is not in the medium tube well and confine it into a single puddle. Use the vacuum pump in the Mercury Spill Control Station to vacuum the mercury.

Note

It's helpful to brush all the mercury that is not in the well into a single puddle towards the rear of the cabinet, then vacuum the one puddle using the mercury vacuum pump.

1. After all excess mercury has been contained, replace the metal tip of the mercury hand pump with a red straw (similar to the red straw supplied with WD-40). Replacing the metal tip of the hose with the red straw will also allow you access to the base of the mercury overflow cup for the medium tube.

Caution

It is mandatory that you remove all mercury from the overflow cup to avoid un-repairable damage to the brass inlet block, rotary valve and solenoid valves.

1. To remove the mercury overflow from the base of the inlet block insert the red straw down the air flow port of the medium tube. Push the full length of the straw all the way down until it reaches the bottom. Elevate the mercury vacuum pump below the tip of the red straw.

2. There should now be mercury in the well of the medium tube where the base of the tube is recessed.

Caution

It is strongly recommended that mercury in the well of the medium tube also be vacuumed out to avoid splashing of mercury during tube installation.

1. When all contaminated mercury is contained and disposed of in the “dirty mercury container,” change your gloves.

2. After the glove change, insert the medium tube from the top of the cabinet. When inserting the tube, slip the dry o-ring over the bottom of the tube. Roll it up the length of the tube before the tube reaches the bottom of the cabinet.

3. Slip the threaded ring nut over the base of the tube. Recess the tube in its well.

4. Push down on the tube from the top of the cabinet and roll the o-ring up until about 3 inches from the bottom of the PVC tube retainer. Grease the o-ring extra-heavy. Use the threaded ring nut to push the o-ring up into the o-ring groove. As you push the o-ring up into the groove, pull down on the tube so the tube is not pushed up out of its well. Secure the threaded ring nut finger tight.

Caution

It is possible to break the tube by over-compressing the o-ring.

1. Change your gloves again.

2. Install the medium piston by softly gripping the top of the piston with your fingers and inserting it into the tube. The groove in the piston should be positioned below the top of the tube, allowing the mercury to form a seal around the piston in the tube.

3. Fill the column of the piston with the triple distilled or specially refined mercury. Use the supplied syringe to force the mercury down the piston’s column. When the mercury level has reached the top, remove the needle and place the metal sonar reflector on top of the piston.

Caution

When a syringe is loaded with mercury, NEVER point the needle downward when away from the Cal-Bench cabinet or a confined tray. Mercury will fall out of the syringe onto the floor contaminating your work area.

1. Release the piston. It should fall to the bottom of the tube.

2. Replace the medium tube spacer and sonar transducer over the tube and secure them with the hold down bracket.

Note

The sonar transducer does not require any special alignment when cleaning or installing the medium or large tube.

1. Fasten the hold down bracket only tight enough to keep it in place.

Caution

Over-tightening the bracket could cause undesirable sonar alignment.

1. Insulation cushions the sonar transducer from the bracket. Tighten the bracket only a few turn with the Phillips driver. The insulation should still appear spongy.

Note

If the sonar bracket that secures the sonar is over-tightened and the insulation becomes permanently over-compressed (flattened), the last reading that the system samples during a calibration can jump high or low causing the current reading to average higher or lower with a one percent of reading error or greater.

1. When the sonar is re-installed, place your mercury syringe and clean mercury container in a plastic tray to avoid spillage. Close the Cal-Bench hood and fasten it down using the two black knobs.

2. Force mercury into the well of the medium tube to seal the base of the tube. The syringe used to load the mercury into the piston can be used for sealing the tube also.

3. The level of the mercury in the well should be approximately 1/8” from the surface of the PVC tube retainer. If mercury stock is low, you may reuse contaminated mercury to seal the base of the tube.

Caution

Never use contaminated mercury to seal the piston. This could cause equipment damage.

1. Deposit any remaining mercury in the syringe to its container. If dirty/contaminated mercury was used, be sure to return the dirty mercury back to the “dirty mercury container.”

Caution

Do not use the syringe that was used for dirty mercury with clean mercury.

1. Return all other supplies to their proper location to eliminate any mercury accidents. Any mercury in the mercury vacuum pump should be poured into the “dirty mercury container” and returned to its proper storage area.

2. Reposition the Plexiglas window in the cabinet.

3. Dispose of your gloves in the mercury disposal can or bag.

4. Disable the solenoid valves (toggle black vent switch on front panel of the Cal-Bench to Manual Vent). Run Leak Test mode from the main menu. Verify the sonar is functioning properly by observing real time values displayed by the system. The sonar is functioning properly if the current reading stays within three counts of the initial reading. If the readings are inconsistent, double check the sonar for any mercury, exit the Cal-Bench software to the root directory and re-boot the system computer. (Re-booting the computer resets the timing sequence of the system.)

5. When the sonar has consistent readings and has passed the Leak Test, re-run the Leak Test mode with the solenoid valves enabled. Run the piston 15” up the length of the tube to check for any leaks. (The Sonar Box should indicate 1.8 for approximately 15”.)

6. This completes the Medium Tube Cleaning Procedure.

Large Tube Cleaning Procedure

Perform this procedure every twelve months.

Warnings

Mercury and Mercury Vapors are toxic! The utmost precaution and care must be taken while transporting and handling mercury. Failure to take appropriate measures when handling mercury could result in hazardous exposure of personnel.

The large tube is heavy and awkward to handle. Do not attempt to remove the large tube from the cabinet without an assistant.

1. Two people should put on latex gloves, goggles (for eye protection) and mercury vapor respirators.

2. Remove the black knobs that secure the hood and flip the hood back.

3. Select Calibrate from the main operational mode menu. Select the large tube. Use a Phillips screwdriver to loosen the metal tabs that secure the large sonar transducer assembly and rotate 180° out of the way. Secure tabs.

4. If the large piston was over-pressurized and mercury is present when you remove the sonar, firmly tap the sonar with a side-to-side motion. Mercury should come out of the sonar transducer. Any mercury that does come out of the sonar assembly should be gathered into a puddle towards the rear of the PVC tube retainer.

5. Wipe down the sonar transducer assembly with a few small Kimwipes to remove any excess mercury that may be left on the transducer or support plate. Rest the sonar assembly in the hood.

6. Contain any mercury that was retrieved from the sonar into a small puddle and vacuum it up using the small hand held pump supplied in the Mercury Spill Control Station.

7. When mercury recovery is complete, place the vacuum pump in the small plastic tray.

8. Remove the Plexiglas window from the front of the cabinet.

9. Loosen the threaded ring nut securing the top of the large tube and pull it down about one foot.

10. Have your assistant push the top sealing O-ring down with a straightened paper clip. (Looking down onto the top of the cabinet you will notice a gap between the tube and the PVC tube retainer. Use a paper clip to push the O-ring down enough to access from the front of the cabinet.) When the O-ring is pushed down, unroll the O-ring down about one foot.

11. Elevate the big tube about one foot over its well.

12. The assistant should use the small acid brush to brush all of the mercury off the base of the tube. Wipe any mercury further up with a small Kimwipe. All of the visible mercury on the exterior of the tube should be wiped off while the tube is held inside the cabinet.

13. When tube is thoroughly wiped of mercury, remove the threaded ring nut and O-ring. Place these items on the plastic tray.

14. Remove the large tube by pushing it up and out through the top of the cabinet. It's best to have one person push the tube up while another pulls it out.

15. Once the tube is out of the cabinet lay it on a clean level table top. Make sure the tube will not roll off the table.

16. Both people should remove their gloves and dispose of them in a mercury container. Put on clean gloves.

17. With two people working on the large tube, one can drain the remainder of the mercury out of the large piston and wipe it clean using the small acid brush. (Often times it's effective to hold the piston and shake the mercury off. Any remaining deposits of mercury are removed using the small acid brush.) After the excess mercury is removed from the piston, wipe thoroughly with ammonia-free glass cleaner and a few small Kimwipes. Be sure to thoroughly dry the piston

Caution

Do not spray glass cleaner directly onto the piston.

1. Clean the large piston target in the same manner as the large piston. When both pieces are clean, place them on the small plastic tray for safe keeping.

2. Contain any mercury that is not in the large tube well into a single puddle towards the rear of the cabinet or back into the well.

Note

Due to the weight of the large tube it is strongly recommended that all mercury in the large tube well be removed using the small hand held vacuum pump in the Mercury Spill Control Station. Removing all mercury from the well significantly reduces splashing if the tube slips during installation.

1. After all excess mercury has been contained, replace the metal tip of the mercury hand pump with a red straw (similar to the red straw supplied with WD-40). Replacing the metal tip of the hose with the red straw will also allow you access to the base of the mercury overflow cup for the large tube.

Caution

It is mandatory that you remove all mercury from the overflow cup to avoid un-repairable damage to the brass inlet block, rotary valve and solenoid valves.

1. To remove the mercury overflow from the base of the inlet block, insert the red straw down the air flow port of the large tube. Push the full length of the straw all the way down until it reaches the bottom. Lower the mercury vacuum pump below the tip of the red straw.

Caution

To prevent mercury contact with arm skin it is strongly recommended that a long-sleeve lab coat be worn for the large tube cleaning procedure.

1. Clean the large tube by spraying ammonia-free glass cleaner into the tube. Roll the tube back and forth across the table to flush the inside of the tube.

2. When the tube is saturated with the cleaner, wipe it out with large Kimwipes. Start at the base of the tube and thoroughly clean the inside first followed by the outside of the tube. Change Kimwipes as often as necessary.

Caution

Always clean the tube inside first to prevent exterior O-ring grease residue from contaminating the inside of the tube.

1. When all contaminated mercury is contained and disposed of in the “dirty mercury container,” change your gloves again.

2. Install the large tube by inserting from the top of the cabinet. Before the tube reaches the bottom of the cabinet, slip the O-ring over the bottom of the tube and roll it up the tube.

3. Slip the threaded ring nut over the base of the tube and then recess the tube in its well.

4. Push down on the tube from the top of the cabinet. Roll the O-ring to 3 inches from the bottom of the PVC tube retainer. Grease the O-ring extra-heavy and push up into the O-ring groove using the threaded ring nut. Secure the threaded ring nut finger-tight.

Caution

To allow for future tube removal, do not over-tighten the ring nut.

1. Replace your gloves again.

2. Install the large piston by gently gripping the top of the piston with your fingers and inserting it into the tube. The groove in the piston should be positioned below the top of the tube allowing the mercury to form a seal around the piston in the tube.

3. Fill the column of the piston with the triple distilled or specially refined mercury. Use the supplied syringe to force the mercury down the piston’s column. When the mercury level reaches the mid-point of the column, remove the syringe and lower the piston about one foot into the tube. Rotate the piston 360 degrees to check the seal around the piston. If there is a gap in the mercury seal, slowly pull the piston back up towards the top of the tube. Refill the mercury column about half-way up the length of the column. When the mercury seal appears intact, position the sonar target on the top of the piston.

Warning

Once a syringe has been loaded with mercury, NEVER point the needle downward when away from the Cal-Bench cabinet or a confined tray. Mercury will fall out of the syringe onto the floor contaminating your work area.

1. Release the piston. It should fall to the bottom of the tube.

2. Re-position the large tube sonar over the tube and secure with the two hold down tabs.

   Note The large tube requires no special alignment of the sonar transducer.

Caution

Do not over-tighten the hold down tabs. This could cause undesirable sonar alignment.

1. Place your syringe and clean mercury container on the plastic tray to avoid spillage.

2. Close the hood of the Cal-Bench cabinet and fasten down using the two black knobs.

3. Refill the mercury syringe and insert the tip of the syringe into the well of the large tube. Fill the large tube well with mercury until the level is approximately 1/8" from the top of the PVC tube retainer base. Refill the syringe with mercury until the appropriate level of mercury is achieved.

Note

If mercury stock is low, you may reuse the contaminated mercury to reseal the base of the tube.

Caution

Never use contaminated mercury to seal the piston. This could cause equipment damage.

1. Deposit any remaining mercury in the syringe to its container. If dirty/contaminated mercury was used, be sure to return the dirty mercury back to the "dirty mercury container."

Caution

Do not use the syringe that was used for dirty mercury with clean mercury.

1. Return all other supplies to their proper location to eliminate any mercury accidents. Any mercury in the vacuum pump should be poured into the "dirty mercury container" and returned to its proper storage area.

2. Reposition the Plexiglas window in the cabinet. Dispose of your gloves in the mercury disposal can or bag.

3. Disable the solenoid valves (toggle black vent switch on front panel of the Cal-Bench to Manual Vent). Run Leak Test mode from the main menu. Verify that the sonar is functioning properly by observing the real time values displayed by the system. The sonar is functioning properly if the *current reading* stays within three counts of the initial. If the readings are inconsistent, double check the sonar for any mercury, exit the Cal-Bench software to the root directory and re-boot the system computer. (Re-booting the computer resets the timing sequence of the system.)

4. When the sonar has consistent readings and has passed the Leak Test, re-run the Leak Test mode with the solenoid valves enabled. Run the piston 15” up the length of the tube to check for any leaks. (The Sonar Box should indicate 1.8 for approximately 15”.)

5. This completes the Large Tube Cleaning Procedure.

Sonar Alignment Procedure

The sonar transceivers must be properly aligned inside each tube. This is easily accomplished on the large and medium tubes, but may require some attention on the small tube. The large and medium tubes are generally self-aligning due to the mounting hardware. The LED display on the sonar module generally will display 2.8 for the large tube and 3.1 for the medium tube when the transceivers are mounted correctly.

The transceiver for the small tube has a small amount of play. Sonar alignment is recommended whenever the small transducer is moved or removed from the top of the small tube. If the sonar transceiver is improperly aligned, the reading on the LED display will be approximately 0.5 to 0.9; or, misalignment may cause excessive variation from flow reading to flow reading. The following procedure will accomplish the best alignment of the small transducer. To begin the sonar alignment procedure:

1. Turn off the computer and sonar box.

2. Remove the four screws from the front bezel of the sonar box. Slide the top cover forward to remove.

3. Connect channel 1 of the oscilloscope to TTL output at pin 9 of U1 on the sonar box motherboard. See Figure 4-1.

4. Connect channel 2 of the oscilloscope to REC output at pin 9 of U1 on the sonar module.

5. Set the volts/division for channel 1 to 2 volts/division. Set the volts/division for channel 2 to 0.5 volts/division.

6. Set the time/division to 1ms.

7. Turn on the sonar box and computer.

8. Leak test the small tube.

9. Enter the Calibrate mode and select the small tube. Set flow to the small tube at 500 SCCM.

10. Remove the black knobs that secure the hood and flip the hood back.

11. Loosen the hold-down bracket on the small tube transceiver.

12. Visually check for and remove any mercury inside the sonar transceiver.

13. Move or rotate the transceiver until an acceptable reading of 3.0 is obtained on the LED display. The waveforms on the oscilloscope should appear as in Figure 4-2.

14. Run flow into the small tube. Check for the smoothest flow displayed in the graph.

15. Repeat steps 13 through 14 until you achieve the smoothest flow.

16. Re-tighten the hold-down bracket. Do not over-tighten the bracket. This could cause undesirable sonar alignment. Close the hood and replace the black knobs that secure the hood. Make sure the waveforms on the oscilloscope have not changed.

17. Replace the top and the bezel of the sonar box.

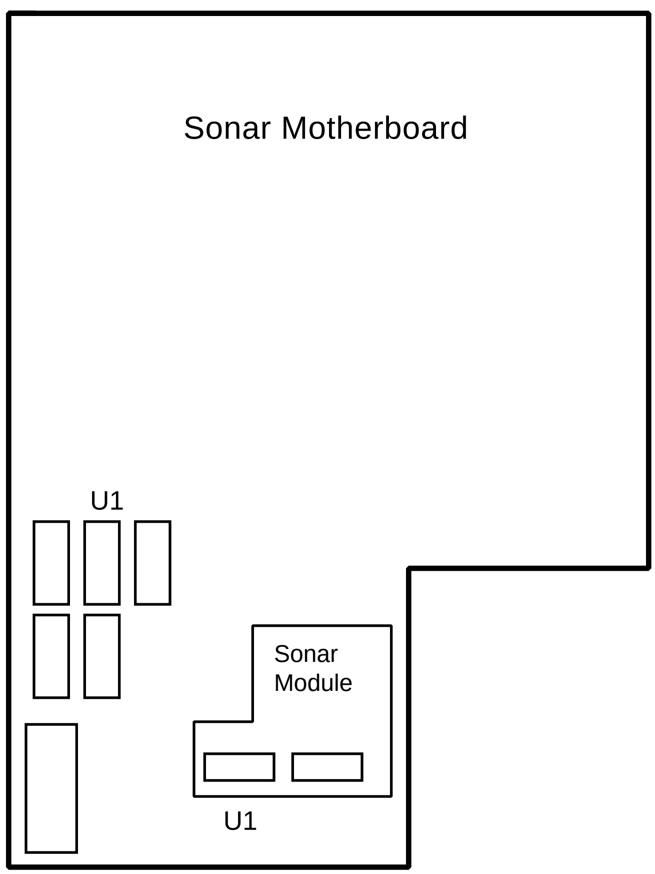


Figure 4-1. Sonar Motherboard

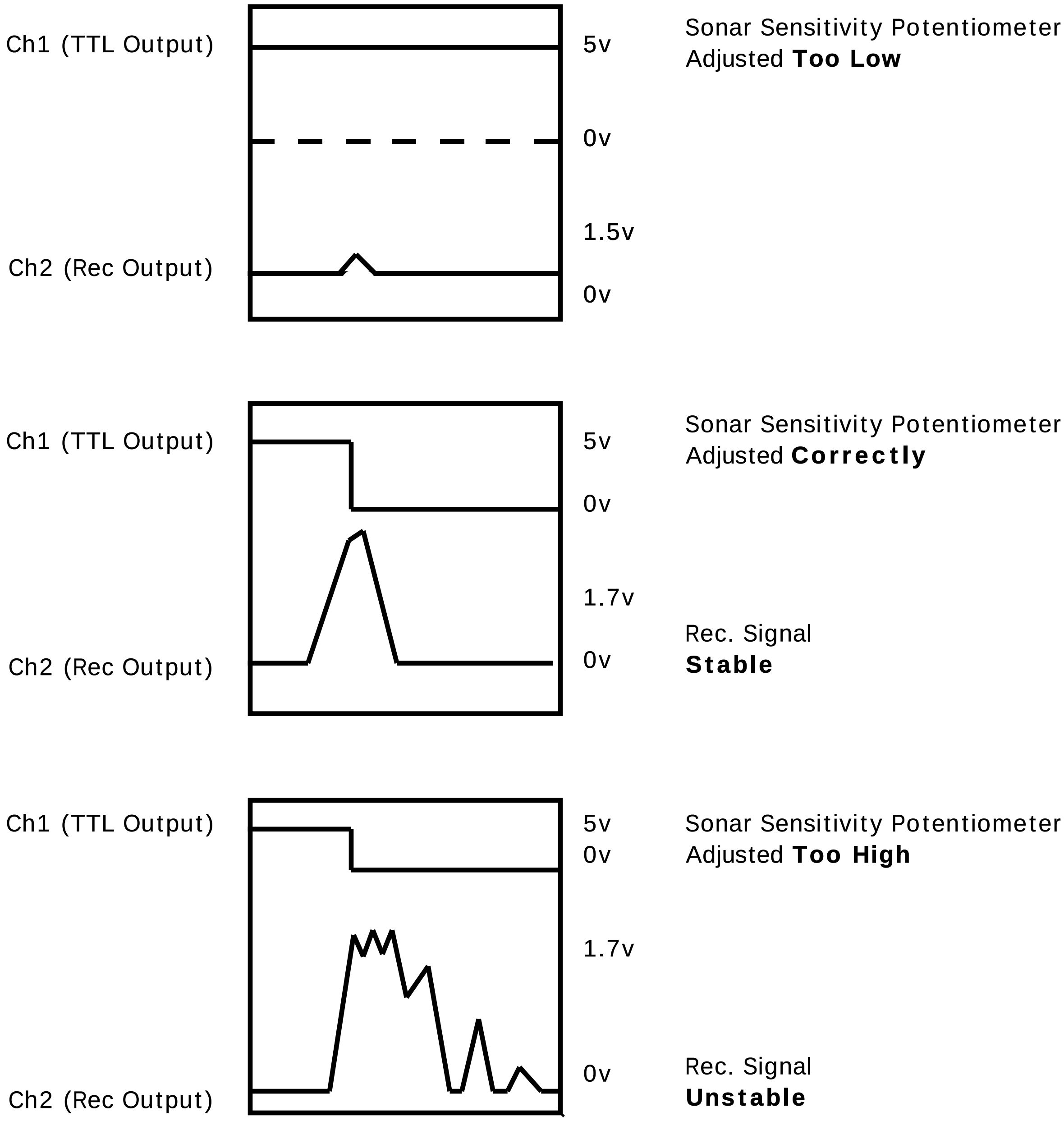


Figure 4-2. Sonar Sensitivity Adjustment Examples

A/D and D/A Calibration Procedures

This procedure is for the A/D and D/A adjustments on the data acquisition board located in the Cal-Bench computer. The board has A/D and D/A converters for controlling the setpoint coming from the computer and reading the output voltage from the mass flow controller under test.

Located on the data acquisition board are two channels of D/A set to output a 0 - 5 volt signal to the controllers (setpoint). Each channel has a Zero pot and a Span pot.

The A/D 16 channel converter module is also on the data acquisition board. Depending on the Cal-Bench configuration, the system uses from two to sixteen channels. A/D adjustment is a **single Zero pot and a single Span pot for all 16 channels.**

The calibration goal of the D/A is to verify with a reliable voltmeter computer output of 0-5 volts. For the A/Ds, calibrate so the computer displays the same voltage as read by the voltmeter. Both the A/D and D/A are calibrated at the same time with the same set up.

The D/A and A/D circuit is load dependent. It is necessary for the MFC to be connected electrically and one MFC plumbed with 30 psig on the inlet side.

The D/A and A/D are calibrated using two Master mass flow controllers (MFCs) plumbed into a gas supply and Control Box Assembly. The load created by the MFCs simulates actual process and produces an accurate calibration.

Procedure Set Up

1. With the computer turned off, remove the screws securing the enclosure and slide the enclosure off.

2. On the Control Box Assembly, set the front panel switches to the **Auto** position.

3. Plumb one mass flow controller into a gas supply. The gas supply may be either bottled gas or from a compressor. Double regulate the gas supply to an inlet pressure of 30 psig. Connect channel 2 cable from the control box to this MFC. Set the second MFC on the work table. It is not necessary to plumb this MFC into a gas supply. Connect channel 1 cable from the control box to this MFC.

4. Turn on the sonar box and control box, then the computer. Select D/A and A/D Adjust from the main menu.

5. Allow a warm-up time of 15–20 minutes for the mass flow controllers.

6. Zero both mass flow controllers to output 0V to +15mV.

Note

The A/D converter does not have the ability to read a negative input voltage. During calibration it is important that both mass flow controllers output a positive signal. To Zero adjust the controller, open the ZERO door and turn the exposed potentiometer until Zero output is 0V to +15mV.

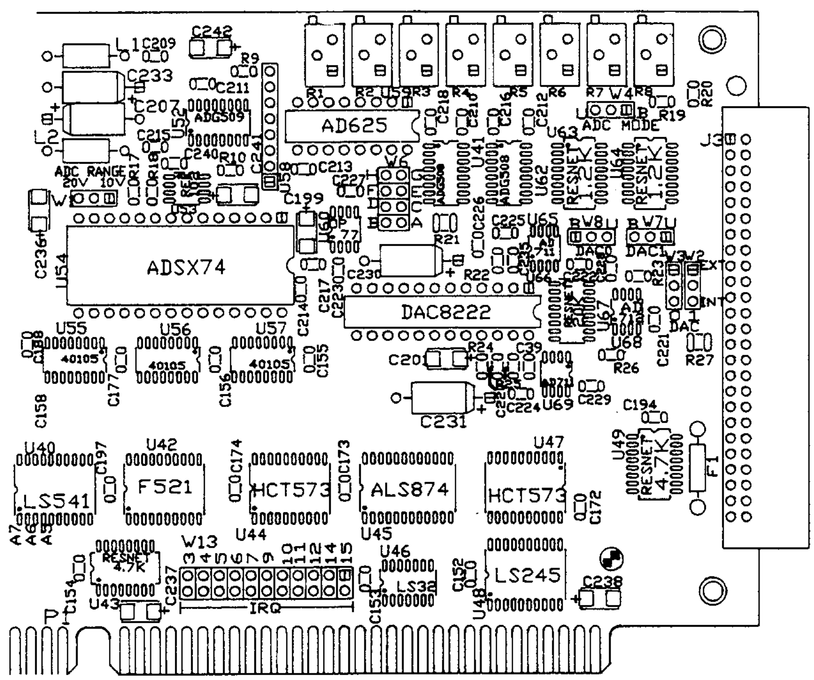


Figure 4-3. D/A and A/D Data Acquisition Board

D/A Adjustment

Adjustments points for the two channels of the D/A converters are shown in Figure 4-3. Each channel has a Zero pot and Span pot. To adjust:

1. Connect your voltmeter to the setpoint input signal at the MFC end of the cable of Channel 1, pin A of the edge card. Reference ground for the voltmeter at pin 2.
2. Change the desired voltage to 0 volts by pressing “C” to C)hange the output voltage. Enter 0. (The software tells the D/As to output a setpoint of 0.0 volts.)
3. Adjust the Zero pot, R7 for Channel 1 until the voltmeter reads 0.000 ± 0.005 volts.
4. Change the desired voltage to 5.0 volts. Press “C” to C)hange the output voltage. Enter 5.0
5. Adjust the Span pot for Channel 1, R5 so the voltmeter reads 5.000 ± 0.005 volts. After your adjustment is made, press “C” to C)hange the output voltage. Enter 0.000. Your voltmeter should indicate 0.000 between pins A and 2.
6. Do not make any adjustments to the Zero for D/A Channel 1 if it does not return to 0.000. Reference the output of the MFC between pins 2 and 3, (pin 3 is out of the MFC), and wait for the output to stabilize between 0V to +15mV. Stabilization may take 3–5 minutes. Do not proceed until the output is stabilized. If the Zero does not return to the original setting, check for leaks and re-zero the MFC. When the output is stable between 0V to +15mV, measure between pins A and 2.

Caution

To avoid out-of-specification calibration you must wait for the MFCs output to stabilize. The D/As may read negative if the MFCs indicates a negative output.

1. Repeat steps 3 through 6 until the setpoint follows the desired voltage.
2. Connect your voltmeter to the setpoint signal at the MFC end of the cable of Channel 2.
3. Repeat steps 3 through 7 for Channel 2, adjusting R3 for Zero and R4 for Span.
4. Fill out the Cal-Bench Certificate of Calibration completely with the information above. Sign the certificate and take to the Quality Engineer for signature. Make copies for in-house files.

A/D Adjustment

Adjustments points for the A/D converters are shown in Figure 4-3. One Zero pot and one Span pot adjust all the A/D channels.

1. Connect your voltmeter to the output of the MFC on Channel 2, pin 3 of the edge card, reference ground to pin 2. Use Channel 2 (The test meter is always on Channel 2 while operating the Cal-Bench in the automatic mode.)

2. Change the desired voltage by pressing “C” to C)hange. Enter 0 volts. The voltage output from the meter is displayed on the lower right side of the screen. The voltage of interest is the “actual” voltage. The “actual voltage” is the output of the MFC plugged into Channel 2.

3. Adjust the Zero pot so the “actual” voltage agrees with the voltage read from the voltmeter. Be careful not to bury the zero. Make sure the output of the MFC is set to 0V to +15mV. Adjust the R8 pot to within ±0.005 volts of the desired voltage.

Note

The voltage output of the MFC must always be measured at the top of the MFC card edge connector on the MFC end. If the voltage is measured at the 50 pin Phoenix connector a slightly lower voltage will be measured. The cause for the lower voltage is due to cable length and the 100KΩ load resistor in the cabling.

1. Change the desired voltage to 5.0 volts. Adjust the Span pot, R1 so the “actual” voltage agrees with the voltage read from the voltmeter to within ±0.005 volts.

2. For each channel used, repeat steps 4 through 6 until the voltages agree at Zero and Span. Allow several minutes between channels for the MFCs to stabilize.

Caution

Before making any adjustment to the A/D Zero pot, verify the output of the MFC has returned to its original setting, 0V to +15mV. The A/D converter is not configured to read a negative voltage and cannot be configured to read a negative voltage for the Cal-Bench system. You must wait 3–5 minutes for the Zero to stabilize.

Do not proceed until the output is stabilized. If the Zero does not return to the original setting, check for leaks and re-zero the MFC. When the output is stable between 0V ± 0V to +15mV, measure between pins A and 2.

1. To avoid out-of-specification calibration you must wait for the output of the MFC to stabilize. Any attempts to reconfigure the board for negative indication can result in irreparable damage to the data acquisition card and void the product warranty

2. When adjustments are complete, fill out the Cal-Bench Certificate of Calibration completely with the information above. Sign the certificate and take to the Quality Engineer for signature. Make copies for in-house files.

Technical Notes

If calibration of the A/D converter is difficult due to noisy output from the MFC, an alternative method may be used. Inject a constant DC voltage from a DC power supply into the A/D converter with the MFC connected to the cable end as indicated in the procedure above. Disconnect the white wire for signal output from the MFC from the cable end. Connect a constant DC voltage to the white wire. DC common from the power supply must be connected to the MFC end of the cable.

System Clock Calibration Procedure

The data acquisition board has a programmable five channel 16 bit counter. This chip is used in the timing of the movement of the pistons.

Timing is generated by a crystal network. The output is then injected into the timing chip to create square wave pulse trains which in turn can be used to count occurrences of events.

Tools and Materials Needed

- Frequency counter with six digit resolution
- two 1” pieces of jumper wire

Procedure Set Up

1. With the computer and frequency counter turn off, insert a 1” piece of jumper wire into pin 33 of the 50 pin Phoenix connector. (The 50 pin Phoenix connector is mounted to the side of the computer case.)

2. Insert a second jumper wire into pin 50 of the 50 pin Phoenix connector.

3. Connect the positive end of the probe lead to pin 50 and reference ground to pin 33.

Caution

Digital ground, pin 33, is the only pin that can be referenced to read the 1.000000 MHz signal generated by the data acquisition card. To avoid permanent damage, do not reference ground to any other point on the computer or the 50 pin Phoenix connector.

1. Turn on the frequency counter and the computer. Wait for the Cal-Bench software to load and the main menu to be displayed on the screen. The clock timing chip is programmable and is initialized at the beginning of the Cal-Bench software.

Clock Calibration

The frequency counter should display 1.0 MHz ± 100 Hz.

1. Allow at least one minute for the frequency counter to stabilize. Record the frequency output. There is no adjustment to increase or decrease the FOUT signal.

2. After recording the frequency output, Q)uit the Cal-Bench software. Turn off the computer and frequency counter.

3. Disconnect the frequency counter. Remove the jumper wires to reduce the possibility of shorting the data card.

4. When calibration is complete, fill out the Cal-Bench Certificate of Calibration (in Appendix B) completely with the information above. Sign the certificate and take to the Quality Engineer for signature. Make copies for in-house files.

902 Control Box Assembly Calibration

The channel 1 and channel 2 display of the 902 control box is set to display between 0 and 100 percent. This allows any 0-5 volt output MFC to be used with the 902 control box. There are three circuits that may need periodic checks or calibration over time. These are the 5-volt reference, the full scale display value and the input circuit that receives the 0-5 volt flow signal from the MFCs.

Adjust 5 Volt Reference

1. Turn off the 902 control box.

2. Remove four screws from the front bezel of the control box. Remove bezel. Slide top cover forward to remove.

3. Connect the positive lead of a voltmeter to pin 2 of U6, LM317LZ. Connect the negative lead of the voltmeter to power common, COM.

4. Turn on the control box.

5. Adjust R58 so the voltmeter reads 5 volts ±0.005.

Adjust Full Scale Display Value

Two adjustment potentiometers adjust the full scale value of the control box, R49 is channel 1 and R48 is channel 2. To adjust the span value of the display:

1. Move the Set/Read switch to the Set position.
2. Select channel 1.
3. Turn the Setpoint potentiometer for channel 1 to the highest value, (fully clockwise).
4. Adjust R49 so the display reads 100.0.
5. Select channel 2.
6. Turn the Setpoint potentiometer for channel 2 to the highest value, (fully clockwise).
7. Adjust R48 so the display reads 100.0.

Adjust Input Circuit

1. Disconnect any MFC that may be connected to the 902 control box.
2. Connect the positive lead of a voltmeter to jumper J2 of channel 1. Connect the negative lead of the voltmeter to power common, COM.
3. Move the Set/Read switch to the Read position. Select channel 1.
4. Inject 0.0 volts into J2. You can use a jumper lead to connect J2 to power common, COM.
5. Adjust R12, zero potentiometer, so the 902 control box display reads 00.0.
6. Inject 5.0 volts into J2. You can use a jumper lead to connect J2 to 5 volt reference, pin 2 of U6, LM317LZ.
7. Adjust R16, span potentiometer so the 902 control box display reads 100.0.
8. Repeat steps 4 through 7 until no further adjustments are necessary.

9. Connect the positive lead of a voltmeter to jumper J2 of channel 2. Select channel 2.

10. Inject 0.0 volts into J2.

11. Adjust R12, zero potentiometer, so the 902 control box display reads 00.0.

12. Inject 5.0 volts into J2.

13. Adjust R16, span potentiometer so the 902 control box display reads 100.0.

14. Repeat steps 10 through 13 until no further adjustments are necessary.

15. Turn off the box. Disconnect the voltmeter and jumpers. Replace the top. Replace the bezel and secure with four screws.

Gas Temperature Probe Calibration

The temperature probe in the Cal-Bench tube cabinet measures the temperature of the test gas flowing through the cabinet. The probe is an RTD type sensor inserted into the gas flow path. The Temperature/Pressure printed circuit board must be calibrated to ensure the correct display of temperature on the front panel of the Cal-Bench cabinet and the correct output voltage to the A/Ds.

Tools and Materials Required:

- One calibrated Fluke 8062A Voltmeter or equivalent
- Cold water bath
- Hot water bath
- One calibrated Omega 866C thermometer or equivalent
- Tweeker

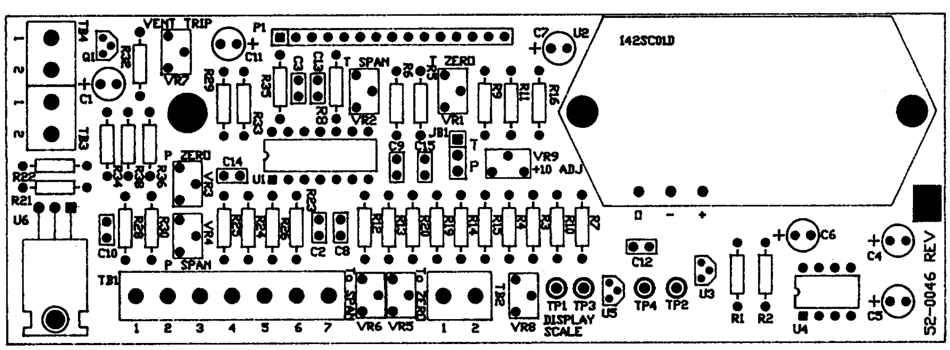


Figure 4-4. Cal-Bench Temperature/Pressure Board

Test Gas Temperature Probe Calibration

1. Place cold water bath next to the Cal-Bench cabinet close enough so the temperature probe can reach the bath. Move the hot water bath next to the cabinet on the opposite side.

2. Turn on the hot water bath. Set hot bath at 89.6°F (32.0°C). Allow the water to warm up.

3. Turn on the cold water bath. Set the cold bath to 50°F (10°C). Allow water to cool down to 50°F.

4. Swing back the Cal-Bench front panel to expose the temperature/pressure board.

5. Locate the display Zero pot, VR1, and the display Span pot, VR2 on the board.

6. Remove the gas temperature probe from the thermocouple feed-through at one end of the motor/rotary valve assembly. Treat the probe gently. The probe is a glass RTD resistor and can break if dropped.

7. Put the probe and the bulb of the thermometer next to each other and wrap a rubber band around the two to be able to move them as a unit between the two baths.

8. Place the probe and thermometer in the cold bath. Allow a few minutes for probe to stabilize.

9. Adjust the temperature Zero pot, VR1 so the display on the front panel of the cabinet agrees with the thermometer. The temperature will be displayed in degrees C.

10. Move the probe and the thermometer to the hot bath. Allow a few minutes for the probe temperature to stabilize.

11. Adjust the temperature Span pot, VR2 so the display on the front panel of the cabinet agrees with the thermometer.

12. Repeat steps 8 – 11 until neither VR1 or VR2 needs adjustment.

Calibration of Auto Input

1. Locate the temperature Zero output pot, VR5, and the temperature Span output pot, VR6, on the temperature/pressure board.

2. Place the red lead of the voltmeter on pin 7 of the 50 pin connector on the computer. Place the black lead of the voltmeter on the ground pin, pin 1, of the same connector.

3. Place the probe and thermometer in the cold bath. Adjust the Zero output pot, VR5 so the voltmeter reads 0.0±0.050 volts. Be careful not to bury the Zero pot.

4. Place the probe and thermometer in the hot bath. Adjust the output Span pot, VR6 so the voltmeter reads 10.0 ± 0.050 volts.

5. Repeat steps 3 and 4 until the output voltage for the cold bath is 0.0 ± 0.050 volts and the output voltage for the hot bath is 10.0 ± 0.050 volts.

6. Convert the temperature reading from degrees C to degrees F. Use Equation 1 to convert from degrees C to degrees F.
   Equation 1: F=(1.8 x C) + 32.

7. Record the temperature as read from the thermometer and the voltage from the A/D connector for the cold bath immersion on the Calibration Certificate in Appendix B. Record the temperature as read from the thermometer and the voltage from the A/D connector for the hot bath immersion on the Calibration Certificate.

8. Calculate the slope using Equation 2.
   Equation 2: Slope = $(Y_2 – Y_1)/(X_2 – X_1)$
   Where: Y_2 = Hot bath temperature (°F)
   Y_1 = Cold bath temperature (°F)
   X_2 = Output voltage when probe is in hot bath
   X_1 = Output voltage when probe is in cold bath

9. Calculate the intercept using Equation 3.
   Equation 3: Intercept = Y_1– (Slope x X_1)
   Where: Y_1 = Cold bath temperature (°F)
   X_1 = Output voltage when probe is in cold bath
   Slope = Calculation from Equation 2

10. Use a word processor in ASCII text mode to edit the CDDF.CFG file. Set line 37 of the CDDF.CFG file to true. Set line 38 to 0.0. Enter the slope on line 39 of the CDDF.CFG file and the intercept on line 40 of the CDDF.CFG file. (See Appendix A for a listing of CDDF.CFG file.)

11. When the information is saved in the CDDF.CFG file, run the program A2DTEST.EXE to watch the A/D results of the calibration. A2DTEST.EXE can be initiated at the DOS prompt by typing the command A2DTEST and pressing ENTER.

12. Compare the temperature displayed by the computer to the temperature displayed by the screen on the tube cabinet. They must agree. If they do not agree, repeat each step until they do.

13. Dry off the probe and reinsert probe into the thermocouple feedthrough so the probe is in the flow path. Tighten down the nut.

14. Fill out the Cal-Bench Certificate of Calibration completely with the slope and intercept calculated above. Sign the Certificate of Calibration. Take the Certificate of Calibration to the Quality Engineer for signature. Make copies for in-house files.

Back Pressure Transducer Calibration

The back pressure transducer in the Cal-Bench™ cabinet is used for two purposes. The first use is the Auto Safety Switch that automatically shuts off the flow when the device senses too much back pressure. Secondly, the transducer is used to A/D the output voltage from the device so the Cal-Bench software can display and use the back pressure value in the measurement of flow. The trip point for the Auto Safety Vent is factory set and the A/D voltage must be calibrated.

Tools and Materials Required

- One calibrated Fluke 8062A Voltmeter or equivalent
- Electronic manometer
- Tweeker
- Nupro shut off valve
- Pressure generating device
- Needle nose vise grip
- Pot glip

Back Pressure Transducer Calibration Set Up

To create a means of leak free pressure of up to 8 inches of water between the manometer and the back pressure transducer, Sierra uses an assembly of vinyl and nylon tubing, fittings and a shut off valve. The assembly is 3/8" vinyl tubing coupled to 1/4" vinyl tubing on the other end. The 3/8" tubing is connected to a branch tee where one outlet of the tee is connected to a shut off valve and the other outlet is connected to 1/4" polyethylene tubing with a compression fitting. Pressure is created by closing the shut off valve and squeezing the 3/8" vinyl tubing with a clamp. The manometer then displays the pressure generated between the pressure transducer and the manometer. Use this tubing assembly in the following calibration procedure.

1. Plug in the manometer and turn it on . Allow 15 minutes for the manometer to warm up.

2. Swing back the Cal-Bench™ front panel to expose the temperature/pressure board. Locate the pressure transducer on the board. (See Figure 4-4.)

3. Remove the tubing from the inlet port of the pressure transducer.

4. Use the compression fitting to connect the tubing assembly to the manometer by slipping the 1/4” vinyl tubing over the inlet port of the pressure transducer. To create pressure, close the shut off valve and squeeze the 3/8” vinyl tubing with a clamp. The manometer will display the pressure generated between the pressure transducer and the manometer. (The shut off valve allows you to vent the pressure to atmosphere.)

5. Place the black lead of the voltmeter on the analog ground pin 1 or pin 2 of the 50 pin terminal strip on the side of the computer case.

6. Place the red lead of the voltmeter on pin 9 of the 50 pin terminal strip on the side of the computer case.

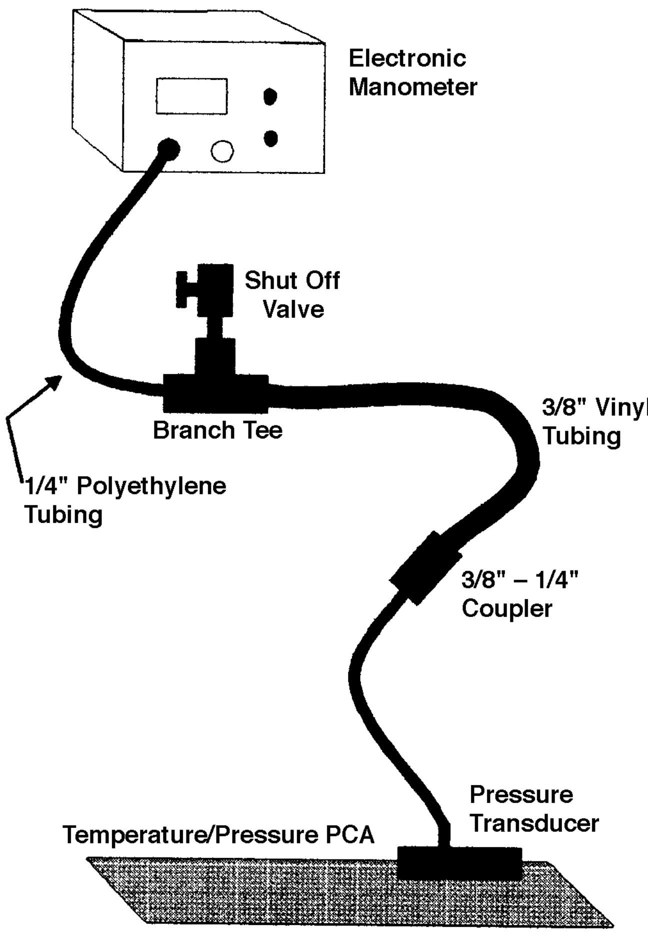


Figure 4-5. Back Pressure Equipment Set Up

Back Pressure Transducer Calibration Procedure

1. Open the Nupro valve of the tubing assembly, in between the manometer and the pressure switch to create zero pressure. Adjust VR3, P Zero so the voltage read by the voltmeter is 0.0 ± 0.050 VDC. Record the voltage from the voltmeter (x) and the inches H_2O from the manometer (y).

2. Close the Nupro valve. Use needle nose vise grip pliers to squeeze the 3/8” tubing to create a pressure of 7.5 inches H_2O between the pressure switch and the manometer.

3. Adjust VR4, P Span so the voltage read is 10.0 ± 0.050 VDC. Record the voltage from the voltmeter (x) and the inches H_2O from the manometer (y).

4. Use Equation 1 to calculate the slope of the line.
   Equation 1: Slope = $(Y_2 - Y_1)/(X_2 - X_1)$
   Where: Y_2 = Full scale pressure (inches H_2O)
   Y_1 = Zero pressure (inches H_2O)
   X_2 = Full scale output voltage
   X_1 = zero output voltage

5. Use Equation 2 to calculate the intercept of the line.
   Equation 2: Intercept = $Y_1 -$ (Slope x X_1)
   Where: Y_1 = Zero pressure (inches H_2O)
   X_1 = Zero output voltage

6. Use a text editor or word processor program in ASCII text mode to edit the CDDF.CFG (ASCII) file. Enter the new values in the CDDF.CFG file. Change line 41 to true, enter 0.0 on line 42, enter the slope on line 43 and enter the intercept of line 44 of the CDDF.CFG file. (See Appendix A for a listing of the CDDF.CFG file.)

7. When information is saved in the CDDF.CFG file run program A2DTEST.EXE to watch the A/D results of the calibration. A2DTEST.EXE can be initiated from the DOS prompt by typing the command A2DTEST and pressing ENTER.

8. Apply zero and full scale pressure to the tubing assembly. Compare the pressure displayed by the computer to the pressure displayed by the electronic manometer. They must agree. If they do not agree, repeat steps 1- 7

9. Disconnect the 1/4” tubing from the pressure switch. Re-install the tubing coming from the brass fittings onto the inlet port of the pressure switch.

10. Fill out the Cal-Bench Certificate of Calibration (in Appendix B) completely with the information above. Sign the Certificate of Calibration and take to the Quality Engineer for signature. Make copies for in-house files.

Ambient Pressure Auto Input Calibration

The electronic barometer used for auto input of ambient pressure is the Setra Model 270. It has a 0-5 volt output for 600-1100 millibars. Cal-Bench™ system software requires a reading of ambient pressure in mm Hg. Millibars must be converted to mm Hg before the slope and intercept can be calculated.

Note

If your facility does not have the equipment necessary to recalibrate a barometric transducer, Sierra Instruments suggests returning the barometer box to the factory for recertification.

Tools and Materials Required

- One calibrated Fluke 8062A Voltmeter or equivalent
- Small Phillips screwdriver
- Small standard screwdriver
- Calibrated primary pressure standard

The 0-5 volt output from the Setra barometer will be A/D so the computer can convert the voltage to mm Hg.

Use Equation 1 to convert millibars to mm Hg.

Equation 1:

$$\text{mmHg} = \text{millibars} \times \frac{29.53000 \text{ inches Hg}}{1000 \text{ millibars}} \times \frac{25.4\text{mm}}{1 \text{ inch}}$$

Perform the calibration on the barometer using your primary pressure standard or by sending the barometer back to the factory for calibration.

1. Use Equation 2 to calculate the slope

   Equation 2: Slope = $(Y_2 - Y_1)/(X_2 - X_1)$

   Where: Y_2 = Full scale barometric pressure (mm Hg)
   Y_1 = Barometric pressure at zero volts output (mm Hg)
   X_2 = Full scale output voltage
   X_1 = Zero output voltage

2. Calculate the intercept using Equation 3:

   Equation 3: Intercept = Y_1–(Slope x X_1)
   Where: Y_1 =Barometric pressure (mm Hg) at zero volts output
   X_1 = Zero output voltage

3. Using a word processing program in the ASCII text mode, enter the new slope and intercept into the CDDF.CFG file. In the CDDF.CFG file, change the Boolean switch on line 49 to true if not already done. Enter 0.0 in line 50, the calculated slope (B) from Equation 2 in line 51 and the calculated intercept (C) from Equation 3 in line 52. See Appendix A for a listing of the CDDF.CFG file.

4. Connect the output cable of the barometer box to the 50 pin connector on the Cal-Bench computer. Tie the red wire of the output cable to pin 4 of the terminal strip. Tie the black wi pin 1 of the terminal strip.

5. Connect the red lead of the voltmeter to pin 4 of the connector. Connect the black lead of the voltmeter to common, pin 1 on the connector. When the system is turned on, you will see the output voltage of the barometer. This is to ensure the output of the barometer voltage is at the input to the A/D.

6. Run A2DTEST.EXE to display the A/D device output on the computer display. Read the ambient pressure from any traceable barometer. Compare the ambient pressure displayed on the computer with the ambient pressure read from the traceable barometer. They should agree. If not, check the values entered into the CDDF.CFG file. Check the input voltage.

7. Fill out the Cal-Bench Certificate of Calibration (in Appendix B) completely with the information above. Sign the Certificate of Calibration and take to the Quality Engineer for signature. Make copies for in-house files.

Ambient Temperature and Relative Humidity Auto Input Calibration

The electronic thermometer and relative humidity sensor used for auto input is a 4-20 mA loop powered transducer. The transducer has both temperature and relative humidity sensors.

The temperature range for the device is –20°F (4 mA) to +140°F (20mA). The calibration points are typically 60°F with a 12 mA output and 90°F with a 15 mA output. The Cal-Bench system software requires the reading of temperature in degrees F.

The relative humidity range for the transducer is 0% (4 mA) to 100% (20 mA) humidity. The calibration points are typically 30% humidity with 8.8 mA output and 90% humidity with an 18.4 mA output.

The output signals must be converted to a voltage because the A/D board can only read voltages. The 4-20 mA signal is converted by sending the current through a 90.9 ohm resistor to ground at the input to the A/Ds. This resistor is factory installed if your Cal-Bench has the auto input option.

Note

If your facility does not have the equipment necessary to recalibrate the ambient temperature probe and the relative humidity sensor, Sierra Instruments suggests returning the transducer to the factory for recertification.

Tools and Materials Required

- One calibrated Fluke 8062A Voltmeter or equivalent
- One calibrated thermometer
- Standard screwdriver and Phillips screwdriver
- Environmental chamber capable of producing temperatures from –20° to 140°F and 0 to 100% humidity

Calibration Setup

1. Turn off the computer, sonar and 902 control box.

2. Remove the knobs that secure the Cal-Bench cabinet top. Flip the top back to expose the sonar transudcers.

3. The transducers are located on the inside of the cabinet top in a weatherproof enclosure. Remove the top of the weatherproof enclosure.

4. Pull the circuit cards out of the enclosure. Disconnect the black and red wires from the temperature circuit card. Disconnect the green and white wires from the humidity circuit card.

5. Pull the power cable out of the enclosure.

6. Push the circuit cards back into the weatherproof enclosure. Replace the top of the enclosure.

7. Remove the weatherproof enclosure from the top of the Cal-Bench cabinet.

8. Take the transducer to your environmental chamber or send it back to Sierra Instruments for calibration. If you decide to send the unit back to the factory for calibration, the unit is returned with the appropriate certificates of calibration and data necessary to update the CDDF.CFG file.

   See below for power connection and 4-20 mA output.

Temperature Circuit Card

Wire Color	Gray Terminal Block	
Black	Pin 1 (+)	+12 VDC
Red	Pin 2 (–)	4-20 mA Output

Relative Humidity Circuit Card

Wire Color	Orange Terminal Block	
Green	+ Pin	+12 VDC
White	– Pin	4-20 mA Output

Temperature Calibration

Points of calibration for the temperature transducer are 60°F with a 12 mA output and 90°F with a 15 mA output. The temperature circuit card has a zero potentiometer, TZ, and a span potentiometer, TS.

1. Power the temperature board with +12 VDC. Zero and span at the two calibration points.

2. Record the temperature from your standard and the output current for the two calibration points.

3. Calculate the voltage the A/D would see when the current is run through a 90.9 ohm resistor to ground. Voltage = current x 90.9Ω.

4. Use Equation 1 to calculate the slope for the voltage versus temperature data.

   Equation 1: Slope = $(Y_2 - Y_1)/(X_2 - X_1)$

   Where: Y_2 = High temperature calibration point (°F)
   Y_1 = Low temperature calibration point (°F)
   X_2 = High temperature calibration point output voltage
   X_1 = Low temperature calibration point output voltage

5. Use Equation 2 to calculate the intercept.

   Equation 2: Intercept = $Y_1 - (\text{Slope} \times X_1)$

   Where: Y_1 = Low temperature calibration point
   X_1 = Output voltage at low temperature calibration point

6. Use a word processing program in the ASCII text mode to enter the new slope and intercept into the CDDF.CFG file. In the CDDF.CFG file, change the Boolean switch on line 53 to true, if not already done. Enter 0.0 on line 54. Enter the slope on line 55 and the intercept on line 56. (See Appendix A for a listing of the CDDF.CFG file.)

Relative Humidity Calibration

Points of calibration for the relative humidity sensor are 30% humidity with 8.8 mA output and 90% humidity with an 18.4 mA output. The relative humidity circuit card has a zero potentiometer, VR1, and a span potentiometer, VR2.

1. Power the relative humidity board with +12 VDC. Zero and span at the two calibration points.

2. Record the relative humidity from your standard and the output current for the zero and span calibration points.

3. Calculate the voltage the A/D would see when the current is run through a 90.9 ohm resistor to ground. Voltage = current x 90.9Ω.

4. Use Equation 1 to calculate the slope for the voltage versus relative humidity data.

   Equation 1: Slope = $(Y_2 - Y_1)/(X_2 - X_1)$

   Where: Y_2 = High relative humidity (%Rh)
   Y_1 = Low relative humidity (%Rh)
   X_2 = High relative humidity output voltage
   X_1 = Low relative humidity output voltage

5. Use Equation 2 to calculate the intercept.

   Equation 2: Intercept = $Y_1 - (\text{Slope} \times X_1)$

   Where: Y_1 =Low relative humidity (%RH)
   X_1 =Output voltage at low relative humidity

6. Use a word processing program in the ASCII text mode to enter the new slope and intercept into the CDDF.CFG file. In the CDDF.CFG file, change the Boolean switch on line 45 to true, if not already done. Enter 0.0 on line 46. Enter the slope on line 47 and the intercept on line 48. (See Appendix A for a listing of the CDDF.CFG file.)

7. Reinstall the temperature and relative humidity circuit cards into the weatherproof enclosure. Mount the unit in the top of the Cal-Bench cabinet. Connect the power cable, see wiring table on page 4-46.

8. Turn on the computer, sonar and 902 control box.

9. Run A2DTEST.EXE to display the A/D device output on the computer display. Read the temperature and relative humidity from a hand held instrument. Compare the temperature and relative humidity displayed on the computer with the hand held instrument. They should agree. If not, check the values entered into the CDDF.CFG file. Check the calibration of the instrument.

10. Fill out the Certificates of Calibration completely with the information above. Sign the certificates of calibration and take to Quality Engineer for signature.

Tube Diameter Certification

The Cal-Bench™ tubes are precision bored borosilicate glass. These tubes have excellent dimensional stability. It is recommended that they be re-certified on a routine basis. Sierra Instruments recommends a three year recalibration period.

The tubes are certified with an air gauge that accurately determines the internal diameter (volume) of each tube. The volume will yield a tube constant, K that is entered into the CDDF.CFG.

Note

Sierra Instruments has a complete set of air gauges and can recertify your Cal-Bench tubes. Modification to the CDDF.CFG file will also be done. Contact the factory for tube shipping instructions.

Tools and Materials Required:

- Air gauge kit (to work with the following master rings):
  0.4986” min ring
  0.5014” max ring
  1.7486” min ring
  1.7514” max ring
  5.6566” min ring
  5.6594: max ring
- Flask for mercury storage
- Fresh mercury
- Syringe for mercury withdrawal and filling
- Mercury Spill Control Station
- Bottle brush and cleaning equipment

See also, Tube Cleaning Procedure Materials Required

Note

Make sure that all test standards are within their calibration dates and are NIST-traceable.

Warning

Mercury and Mercury Vapors are toxic! The utmost precaution and care must be taken while transporting and handling mercury. Failure to take appropriate measures when handling mercury could result in hazardous exposure of personnel.

Tube Certification Procedure

1. Remove the tubes from the Cal-Bench™ following the instructions in the Tube Cleaning Procedure.

2. Record ambient temperature, ambient pressure and relative humidity at the time of actual measurement on the tube certification form in Appendix B.

3. Use the appropriate inside air gauge to measure the inside diameter of the tube with a minimum of 24 data points spaced no more than one inch apart. Record the data points on the Tube Certificate of Calibration.

4. Calculate the mean tube diameter using the supplied form and using standard averaging methods. Compare the value obtained with the value of the previous calibration and note any change.

5. The K factor that the area of the tube is calculated from:

$$K = \frac{\pi \{\text{Grand Average (cm)}\}^2}{4}$$

6. Compare this value to the value given in the CDDF.CFG file. Contact the factory and advise if your values differ from the value given for each tube. The CDDF.CFG file will have to be modified for the new values.

7. Reassemble the tubes following the instructions in the Tube Cleaning Procedure.

8. Using a non-document mode word processor, enter the calibration date and recalibration date in the CDDF.CFG file.

9. Fill out the Cal-Bench Certificate of Calibration (in Appendix B) completely with the information above for each tube. Sign the Certificate of Calibration and take to the Quality Engineer for signature. Make copies for in-house files.

Correction Factor Procedure

This procedure is necessary in or order to null out any "errors" in the Sonar Measurement due to non-ideal behavior of the sonar transducer. It is also employed by users who purge the sonar transducer with a gas other than air to correct readings. The procedure instructs you to compare the readings of distance by the sonar to the actual distance measured by a precision rule. The procedure for determining the tube correction factor is described below.

Tools and Materials Required:

- NIST certified precision rule.

Note

This procedure can only be done after all ambient condition devices have been certified.

1. Make a back-up copy of CDDF.CFG file. Name the copy CDDF.ORG.

2. Using a non-document mode word processor, change the correction factors for all three tubes to 1.00 in the CDDF.CFG file.

3. Turn on the Cal-Bench and load the new CDDF.CFG file.

4. Select Verify Sonar and choose the large tube. "Equilibrate" the air volume by moving the big piston up and down approximately 22 inches at least four times within four minutes.

5. Enter the correct values for "ambient conditions."

6. Select measurement units, either inches or centimeters.

7. Secure a precision rule to the outside of the glass tube so the bottom of the rule is resting firmly on the bottom plate of the tube cabinet.

8. Enter the “zero” value by sighting across the top of the piston striving to minimize parallax. Press ENTER. If the resultant average deviation is greater than 0.50, press ESCAPE to re-run the test. Make sure you do not jar or move the table. Press the ENTER key gently.

9. Move the piston up the tube about 22 inches (56 cm). Control the flow into the tube with the needle valve. When the piston is approximately 22 inches (56 cm) from the bottom of the tube, shut off the flow of gas with the shut off valve. Let the piston stabilize for 30 seconds.

10. Measure the top position distance from the rule to the top of the piston in the same manner used for the zero distance. Enter the measurement into the computer. Press ENTER.

11. Record the system distance and the measured distance on the Certificate of Calibration from the Results of Sonar Verification box on the computer display.

12. Repeat steps 6 through 11 for ten sets of data points.

13. Add the ten values recorded for measured distance. Add the values for the system distance. Record the results in total lines.

14. Calculate the mean value by dividing the measured value by the system value.

15. Repeat these steps for each tube.

16. Using a non-document mode word processor, insert your new values in the CDDF. CFG file.

17. Re-boot the Cal-Bench program and check the results by running through the Verify Sonar Calibration again with the new correction factors for each tube.

Cal-Bench Software Validation

The purpose of this document is to give the users of the Cal-Bench™ a procedure for validating the system software. This is important due to the increasing popularity of ISO-9000 and the needs of the nuclear industry.

The validation process consists of taking a number of readings with the Cal-Bench system in its normal operating "Calibrate" mode and comparing the results with readings taken manually.

The goal is to have readings within a few percent. The difficulty with the manual validation method is the location of the piston within the glass cylinder and the hand eye coordination challenges using the stop watch. The Cal-Bench system can locate the piston within 0.006" while the manual method is 0.08." This discrepancy can be greater than 2% of reading and is random. Therefore, taking many runs will minimize the errors.

Tools and Materials Required:

- Hard copy of your system CDDF.CFG file
- Precision rule
- High quality mass flow controller full scale flow of 5000 SCCM
- Sports-style stopwatch able to measure to 0.01 of a second
- Cal-Bench validation data sheet (page 4-61)

CDDF.CFG FILE INFORMATION		
Line No.	File Information	Description
1	Sierra Instruments (R&D Bench)	User Name
2	5 Harris Court, building L	User Street Address
3	Monterey, CA 93940	User City and State Address
4	1067	System Serial Number
5	02/22/96	Date Sold
6	Asset No. 0296	P.O. Number
7	1028	Large Tube Serial Number
8	2028	Medium Tube Serial Number
9	3028	Small tube Serial Number
10	162.23884	Large Tube Constant
11	15.52882	Medium Tube Constant
12	1.26588	Small Tube Constant

1. Note the tube constants from your CDDF.CFG file. The first 12 lines of a sample CDDF.CFG file are given in the table above. Note and record the tube constant for the tube under test.

2. Use a precision rule to make a “zero” mark approximately 8 cm above the surface of the tube holder. Then mark 56 cm (22 inches) above that mark. This mark must be within 0.01” to be valid.

3. Adjust a high quality mass flow controller to an appropriate flow for the tube under test. We suggest flows of:

   - 500 SCCM small tube
   - 1000 SCCM medium tube
   - 5000 SCCM large tube

4. Update all of the variables as you would during a normal calibration. Once the flow is known to be stable and the system is at thermal equilibrium, take at least ten test runs over the marked distance on the tube. Use a stopwatch to time in seconds how long it takes the piston to pass the full distance.

5. Initiate the flow measurement run on the Cal-Bench. When the piston reaches the “zero” mark, start the stopwatch. As the piston reaches the top mark, stop the stopwatch. Stop the flow measurement. Record the time in seconds that the piston traveled between the two marks. Record the ambient pressure, gas temperature, back pressure, distance the piston traveled and the flow measured by the Cal-Bench system. You may read the gas temperature and back pressure from the computer display screen.

6. Run the test ten times. Record the data for each run. Calculate the total for each column on the data sheet. Calculate the average for each column on the data sheet. Use the calculated averages in the calculations below.

7. Use Equation 1 to convert inches to centimeters if necessary.

   Equation 1:

   $$Cm = In \times 2.54$$

8. Calculate the volume swept out by the piston using Equation 2. You may have to correct based on the true distance between the marks.

   Equation 2:

   Volume = Distance (cm) * Tube Constant (cc/cm)

9. Calculate the pressure correction factor for the actual pressures. Calculate the actual pressure within the cylinder during the calibration run. This is done by adding the back pressure created by the piston to the ambient pressure and divide this by the STP conditions of 29.92 in Hg. This result will yield a pressure correction factor. See Equation 3.

   Equation 3:

$$PCF = \frac{\left[\left(\frac{\text{Back Pressure (In. H2O)}}{13.6}\right) + \text{Ambient Pressure (In. Hg)}\right]}{29.92}$$

10. Calculate the temperature correction factor. Calculate the temperature correction factor using the Rankine scale. This is done by adding 459.67 to degrees F. Divide the STP temperature by the measured gas temperature in °F. See Equation 4

    Equation 4:

$$TCF = \frac{70 + 459.67}{\text{Gas Temperature (F)} + 459.67}$$

11. Convert the time from seconds to minutes using Equation 5.

    Equation 5:

$$\text{Minutes} = \frac{\text{Seconds}}{60}$$

12. Calculate the flow from the time the piston took to sweep out the distance of travel using the correction factors above. Use the time recorded above. See Equation 6.

Equation 6:

$$\text{Flow} = \frac{\text{Volume (cc)} * \text{PCF} * \text{TCF}}{\text{Time (minutes)}}$$

13. Compare this reading to the Cal-Bench™ System. Use Equation 7 to calculate the % error.

Equation 7:

$$\%\ \text{Error} = \frac{\text{Calculated Flow - Cal-Bench}}{\text{Calculated Flow}} * 100$$

Example Using the Medium Tube

In our example we will be validating the medium tube. The medium tube constant in this example is 15.52882 cc/cm as shown in the table above. This means for every upward movement of 1 cm the volume displaced by that movement is 15.52882 cubic centimeters. The flow controller for our example is set to flow 1000 SCCM in the medium tube.

The following data is an example of one test run on the medium tube.

Data:

Gas Temperature (°F)	72.5
Ambient Pressure (In. Hg)	29.74
Back Pressure (In. H2O)	1.979
Time (seconds)	51.42
Distance (In.)	22.0
Cal-Bench flow (SCCM)	1002.213

1. Convert the distance swept out by the piston to centimeters using Equation 1.

   Cm = 22.0 in. x 2.54 = 55.88 cm

2. Calculate the volume for the distance the piston traveled using Equation 2.

   Volume = 55.88 cm x 15.52882 cc/cm = 867.75 cc

3. Correct the pressure using Equation 3:

   PCF = ((Back Pressure/13.6) + Ambient Pressure)/29.92
   = ((1.979/13.6) + 29.74)/29.92
   = 0.999

4. Correct the gas temperature using Equation 4:

   TCF = (70 + 459.67)/(Gas Temperature + 459.67)
   = (529.67)/(72.5 + 459.67)
   = 0.995

5. Convert seconds to minutes using Equation 5:

   Minutes = 51.42/60 = 0.857 minutes

6. Calculate the flow using Equation 6:

   Calculated Flow = Volume * PCF * TCF / Minutes
   = 867.75 cc * 0.999 * 0.995/0.857
   = 1006.474 SCCM

7. Calculate the % error between the Cal-Bench system flow and the measured flow using Equation 7.

   % Error = [(1006.474–1002.213)/1006.474] x 100 = 0.423%

This completes the Cal-Bench software validation procedure.

Cal-Bench™ Software Validation Data

Date:________________________________Technician:____

Cal-Bench Asset No.:__________________Tube Serial No.:______________________________________

Tube K Factor:________________cc/cm Tube: Large_________Medium_______Small_________

No.	Distance (Inches)	Gas Temperature °(F)	Back Pressure (In. H2O)	Ambient Pressure (In HG)	Time (Seconds)	Cal-Bench Flow (SCCM)	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Total							Calculated Flow SCC
Average							

1. cm = in x 2.54 =________________________cm
2. volume = distance (cm) x K factor (cc/cm) =__________________________cc
3. PCF = ((back press/13.6) + ambient press)/29.92 ______________________
4. TCF = (70 +459.67)/(gas temp + 459.67) =___________________________
5. min. = seconds/60 = ___________________________min.
6. calculated flow = (volume x PCF X TCF)/time =____________________________SCCM
7. % error = ((Calculated flow - Cal-Bench flow)/Calculated flow) x 100

% Error = (______________ – ______________) / ____________________ x 100 __________ %

Bell Prover Option Certification

This procedure outlines a method for certifying the Cal-Bench primary flow standard bell prover and defines the method used to measure the volume of the bell. The volume will yield a tube constant, K, that will be entered into the CDDF.CFG file used by the program in calculating mass flow rate from the volumetric displacement.

Tools and Materials Required:

- OD Pi Tape with a range of 12 - 36” for the 5 cubic foot bell
- OD Pi Tape with a range of 24 - 36” for the 20 cubic foot bell
- 0 - 1” Deep throat micrometer with spherical tip

Make sure that all test standards are within the calibration date and are NIST traceable. To certify bell volume:

1. Raise the bell to its full upward extension.
2. Be sure the bell is free of oil, water, and any other contaminants that could effect proper measurement.
3. Remove bell. Set bell on its side.
4. Use a flexible metal rule and a pencil, mark the bell in 2” vertical increments at 90° intervals around the inside of the bell. These marks will be location marks for the Pi tape.
5. Record ambient temperature, ambient pressure, and relative humidity and the asset tag number from those devices at the time of actual measurement on the bell prover certification form. These measurements are for reference purposes only and are not used in any calculations.
6. Use the Pi tape to measure the bell at each of the 2” vertical increments marked in step 4. Record readings on the bell prover certification form.
7. Measure thickness of bell at ten equidistant locations at the bottom of the bell.
8. Calculate the Mean O.D. by filling out the bell prover certification form.
9. Calculate the Mean thickness by filling out the bell prover certification form.

10. Subtract two times the Mean thickness from the Mean O.D. to find the Mean I.D.

11. Calculate the area of the bell prover. The K-factor from which the area of the bell prover is calculated as:

$$K = \frac{\pi(2.54 \text{ x MEAN I.D.})^2}{4}$$

    Compare this value to the value given in line 73 or line 105 for second bell prover, of the CDDF.CFG file. Advise the factory if your values differ from the value given. The CDDF.CFG file will have to be modified for the new value.

1. Reinstall the bell.

Bell Prover Option Correction Factor

The procedure for determining the bell prover option correction factor is described below.

Tools and Materials Required:

- one NIST certified precision rule

The correction factor procedure is necessary to null out any "errors" in the linear encoder measurement. The procedure will instruct the user to compare the readings of distance by the linear encoder to the actual distance measured by the precision rule. This procedure can only be done after all ambient condition devices have been certified.

1. Follow the instructions in Appendix A to change the CDDF.CFG correction factors for the linear encoder to 1.00 (use a word processor in non-document mode). Before changing the CDDF.CFG file, make a backup copy the original file named CDDF.ORG (for original). When you have changed the constant (line 78 for the 5 cubic foot bell or line 110 for the 20 cubic foot bell) to 1.00 you are ready to turn on the Cal-Bench system and load the new CDDF.CFG file.

2. Select verify sonar and choose the prover. "Equilibrate" the air volume by moving the bell up and down approximately 22 inches at least four times within four minutes.

3. Enter the correct values for "ambient conditions."

4. Select measurement units, either inches or centimeters.

5. Raise the bell and secure the precision rule to the outside of the bell so that the bottom of the rule is resting firmly on a reference surface. Affix a pointer on the outside of the bell prover rim in a position that will allow a parallax-free sighting of the ruler markings.

6. Enter the “zero” value by sighting across the pointer striving to minimize parallax. Press ENTER. If the resulting average deviation is greater than 0.50 then press ESCAPE to re-run the test. Make sure you do not jar or move the bell. Press ENTER key gently.

7. Raise the bell about 22 inches. Control the flow into the bell with a needle valve. When the bell is 22 inches from the bottom, shut off the flow of gas with the shut-off valve. Let the bell stabilize for 30 seconds.

8. Measure the top position distance from the rule to the top of the bell in the same manner used for the zero distance. Enter the measurement into the computer. Press ENTER.

9. Record the system distance and the measured distance on the Cal-Bench bell correction factor certificate of calibration sheet from the results of the sonar verification box on the computer display.

10. Repeat steps 4 through 9 for ten sets of data points.

11. Add all of the ten values of the measured distance and all ten values of the system distance. Record the sums on the certificate of calibration sheet.

12. Divide the sum of the measured distances by the sum of the system distances. This is the new correction factor.

13. Use a non-document mode (ASCII) word processor to insert your new values in line 78 or line 110 of the CDDF.CFG file.

14. Re-boot the Cal-Bench software and check the results by running through the verify sonar calibration again with the new correction factors for the bell.

Chapter 5 Troubleshooting

Warnings

To avoid potential electric shock, follow local Electric Code safety practices when troubleshooting or repairing this system. Failure to do so could result in injury or death. Only qualified persons should perform service on the Cal-Bench system.

Always remove main power before replacing any fuses, switches or components of the Cal-Bench system.

Mercury and mercury vapors are toxic! Exercise extreme caution when transporting and handling mercury. Failure to take appropriate measures when handling mercury could result in hazardous exposure of personnel.

Hardware Problems

Problem	Possible Cause	Solution
Piston rises erratically	· Dirty tube	◊Clean tube. See Tube Cleaning Procedure in Chapter 4.
	· Dirty mercury	◊Change mercury. Use only triple distilled mercury. See Tube Cleaning Procedure in Chapter 4.
	· Ambient temperature too high	◊Ambient temperature must be between 18°C and 23°C.
Piston takes long time falling	· Dirty tube	◊Clean tube. See Tube Cleaning Procedure in Chapter 4.
	· Exhaust line is restricted	◊Remove exhaust line to determine if this will eliminate problem. Replace line if needed.
Gas will not flow through tubes	· Manual Vent Open on cabinet	◊Turn Manual Vent to the “On” position, (flip switch up).
	· Auto Safety Vent activated	◊Reset Safety Vent (LED will be on). Eliminate condition causing high pressure to the Cal-Bench system.
	· Auto Safety Vent will not reset	◊Reduce gas pressure to the Cal-Bench system.
	· Sonar not aligned	◊Follow Sonar Alignment Procedure in Chapter 4 for each tube.

Software Error Messages

Error Message	Possible Solution
· Can't find "CDDF.CFG" in current directory Can't find "HERC.BGI" in current directory	◊ These files must be located in the same directory as the main program SIERRA.EXE. It is recommended that you keep a backup of the original software program supplied with the Cal-Bench system.
· Can't find "GAS.TBL" in current directory Can't find "BA.BRK" in current directory	◊ The path to the locations of these files is specified in the CDDF.CFG file. Ensure that these files are located as indicated in the CDDF.CFG file or change the CDDF.CFG file with an ASCII text editor or word processor in the non-document mode.
· Printer error	◊ Verify printer operation. Check printer manual for troubleshooting procedures.
· Can't read record	◊ Make sure that the records are stored in the path specified in the CDDF.CFG file.
· No such record	◊ Make sure that the device serial number is entered correctly.
· Breakpoint file corrupted	◊ Error in storing data in the breakpoint file. See Appendix A for instructions in creating your own Breakpoint files.

Error Message	Possible Solution
· Master cannot generate enough flow	◊ The Master flow controller is unable to generate the flow anticipated by the Cal-Bench system. Check the gas lines, vent and remainder of system to ensure there are no obstructions between the Master and the Cal-Bench calibration tubes.
· Flow is too low for this tube	◊ This error message will only appear in the Generate mode and Final Q.C. mode when you override the tube automatically selected by the program. You have selected a tube that is inconsistent with the flow rate used. This is permitted in the Manual mode.
· User MUST enter data as shown	◊ Prior to proceeding into any calibration option of the program, all data shown in the main screen must be entered. If this message appears, press ESCape to remove the error message and enter the correct information for all fields in the main display.
· BGI error: Graphics not initialized (use init graph).	◊ Ensure that HERC.BGI is in the same directory as SIERRA.EXE and that BA.BRK and GAS.TBL is in the path specified by the CDDF.CFG file.
· Program operation “hang-up”	◊ Make sure the originally supplied AUTOEXE.BAT file has not been altered. ◊ Verify that all TSR programs have been removed from memory.

Error Message	Possible Solution
· Program gives "strange results"	◊ From the main menu, select "Calibrate" and press the "X" key to load factory test data. Run flow to check if problem repeats.
· Errors in the deviation graph	◊ Verify that the full scale flow is correct.
· Program will not retrieve a record	◊ Check to see if there is a leading space in the filename. If so, rename the file.
· DISPLAY.CFG file missing	◊ This file must be located in the same directory as the main program SIERRA.EXE. We recommend keeping a backup copy of the original file supplied with the Cal-Bench System.
· VGA requires at least 1 Mb of EMM memory Could not setup EMM memory for VGA	◊ The software checked for 1 megabyte of free expanded memory to be used for color VGA and did not find enough free memory. Make sure your computer has at least 4 Mb of memory and only the Cal-Bench software running.
· VGA requires at least 1 Mb of XMM memory Could not setup XMM memory for VGA	◊ The software checked for 1 megabyte of free expanded memory to be used for color VGA and did not find enough free memory. Make sure your computer has at least 4 Mb of memory and only the Cal-Bench software running.
· Failed to setup video	◊ Error message as a result of one of the two listed above.

Error Message	Possible Solution
· Failed to setup font	◊ Software failed to find either Bit5x8.GFT or Bit8x8.GFT files. These files must be located in the same directory as the main program SIERRA.EXE. We recommend keeping a backup copy of the original file supplied with the Cal-Bench system.
· Serial number not specified	◊ The serial number of Device Under Test was not entered.
· Filename already exists	◊ Software found an existing file. Use a different filename.
· Failed to detect extended memory	◊ Software did not find HIMEM.SYS or compatible extended memory manager present.
· Cannot set printer driver	◊ An error occurred while opening the printer driver library. Check for corrupted printer driver file.
· Cannot find driver	◊ An error occurred while opening the printer driver file. Check for missing printer driver file. File should be in the same directory as the main program file SIERRA.EXE.
· Cannot find library	◊ An error occurred while opening the printer driver library. Check for missing printer driver library file. File should be in the same directory as the main program file SIERRA.EXE.
· Printer not ready	◊ Verify that printer is turned on and set to on-line.

Appendix A Software Data

Included in Appendix A are these additional software procedures:

System Configuration Files

The system configuration files contain all the specific information and software default conditions unique to your Cal-Bench operating system. Beginning below is information on the CDDF.CFG file with an explanation of each entry. On the following pages are the Display.CFG file, the Color.CFG file and the Printer.CFG file. Additional data following the Calibration Report Example covers the Custom.CFG and Report.CFG files.

CDDF.CFG File

You may want to change information contained in the CDDF.CFG. This may occur when changing any of the standard default conditions or after calibrating any of the auxiliary devices. When changing any file it is imperative that the proper format be followed.

1. When making changes to the CDDF.CFG file, first make a backup copy of the file. The Cal-Bench software program will not run without the CDDF.CFG file, nor will it run properly if the CDDF.CFG file has bad data or is corrupted.

2. To make changes in the CDDF.CFG file use a word processor to retrieve the file and store the modifications in a non-document, ASCII, mode. Failure to do so may result in improper operation of the Cal-Bench system software.

3. Each line of data occupies 30 spaces before the semicolon. The 30 spaces must be maintained for each line in the CDDF.CFG file for proper operation.

The following text discusses each portion of the CDDF.CFG file with line number references.

Changing Flow Units

The software uses a default condition of measuring flow in SCCM. The software also recognizes SLPM, SLPH, SCIM, SCFM, and SCFH.

To use a different flow unit for default conditions:

· Change SCCM to another recognized unit. Enter the new flow unit in CAPITAL letters with no leading spaces. (Line 16.)

The software will also permit the use of user defined flow units. To define your own units of flow measurement, replace "Other" in CDDF.CFG file with the selected units and, on the next line, enter the multiplication factor relative to SCCM.

For instance, if you want the default conditions to be SCCH (standard cubic centimeters per hour):

1. Enter SCCH in place of "Other" and on the next line enter the multiplication factor of 0.016667 (1/60).

2. Determine the number of decimal places for the display of flow in your user defined flow units. Enter this number on the next line; the default is 1 place. (Lines 17, 18 and 19.)

Calibration Dates

Calibration and calibration due dates are listed in the CDDF.CFG file. When the device calibration is due, a reminder notice will appear when loading and exiting the system. After the device is calibrated, it is necessary to change the last calibration date and the calibration due dates in the CDDF.CFG file. (Lines 20 - 31 and 57-68.)

Temperature Default

Default conditions for temperature can either be degrees C or degrees F. To change, enter the new default conditions without any leading spaces. The units for reference temperature must be entered in °F. The program will convert this entry to the selected units on the screen. Standard temperature is industry dependent. The process industry typically uses 70°F, the natural gas industry uses 60°F while the semiconductor industry uses 32°F (0°C). (Lines 32 and 33.)

Pressure Default

The default conditions for ambient pressure and standard pressure are mm Hg, In Hg, or PSIA. Use these exact terms when changing default conditions without leading spaces. In addition to the above units, back pressure can also be measured in In H_2O. (Lines 34, 35 and 36.)

Automatic Inputs

When using automatic input of ambient conditions, a Boolean flag in the CDDF.CFG file tells the computer if the external device is connected to the A/D converter. "False" indicates no external device and "true" indicates the presence of an external device at the A/D. The software will accept the signal from the device that is linear or follows a quadratic formula in the form of $Ax^2 + Bx + C$. This information is entered into the CDDF.CFG file in the following manner:

true... Boolean switch for measuring external device input by AD

0.0	... A of $Ax^2 + Bx + C$
40.0	... B of $Ax^2 + Bx + C$
–200.0	... C of $Ax^2 + Bx + C$

The A/D for the device is currently turned on. The device is linear since A of the quadratic is 0. The slope is then 40 with the intercept of – 200. (Lines 37 - 56.)

The operating software is written to accept a 0-10 VDC output signal from the external devices. The output must either be linear or follow a quadratic equation. Temperature must be in °F, pressures in mmHg and relative humidity must be 0-100%.

DOS Path

The CDDF.CFG file also lists the default DOS paths where the program can find the location of Breakpoint files, the gas table and the storage of the records. Lines 69 - 71.

Lines 72 - 86 of the CDDF.CFG file is data for Sierra's 5 cu. ft. bell Prover which may be integrated to the system in the future.

Lines 86 - 89 are Boolean switches for the computer card.

Lines 90 - 92 are the default back pressure for the large tube, the medium tube and the small tube.

Line 93 is the maximum safe flow.

Line 94 is a Boolean switch for testing software and line 95 is the Boolean for enabling the RS485 communication.

Lines 96 - 98 of hexadecimal numbers are the address of the RS485 communication board, the communication port number and the baud rate of the board. The RS485 communication board is for future use.

Lines 99 - 103 of the CDDF.CFG file are the user changeable descriptions of the information for the Device Under Test. The user may change these descriptions to conform with their documentation standards.

Lines 104 - 118 are data for an optional second Bell Prover which may be integrated to the system in the future.

Lines 119 - 121 are for setting the default near range parameters for when the Bell Provers will cut off and a Boolean for Cal-Bench systems having only a single Bell Prover with no calibration tubes.

Lines 122 - 127 are for enabling RS-232 communication.

Line 128 is a default description used in the Device Under Test window. Line 129 is the default test gas.

Lines 130 - 134 of the CDDF.CFG file are the default movement increments for each of the tubes and for each Bell Prover.

Line 135 is to enable the software for the type of data acquisition card used in the system.

Remove this page and insert:

CAL-BENCH MAIN CONFIGURATION FILE

Backside of

Remove this page and insert:

CAL-BENCH MAIN CONFIGURATION FILE

Display.CFG File

Display.CFG enables the software to use VGA or Hercules monochrome monitor. The file contains two Boolean switches. The first Boolean determines the display type. The Boolean set to “true” indicates the display type is a VGA monitor. A “false” indicates a Hercules monochrome monitor.

The second Boolean switch allows the software to use expanded memory or extended memory. The software requires 1 megabyte of expanded or extended memory for the VGA monitor. The Boolean set to “true” indicates to the software to use the expanded memory. The Boolean set to “false” indicates to use extended memory.

Make a backup file of the Display.CFG file before making any changes to it. Use a word processor to retrieve the file and store modification in a non-document mode. Failure to do so may result in improper operation of the Cal-Bench system.

Color.CFG File

Color.CFG file is the configuration file for setting the color for letters, background fields, headers, box outlines and graphic displays. A copy of the Color.CFG file with a description for each line is included.

Each line of data occupies 30 spaces before the semicolon. The 30 spaces must be maintained for each line of the Color.CFG file for proper operation. Three lines of header must be included in the file. The software skips the first three lines then reads each line of data from the file.

Make a backup file of the Color.CFG file before making any changes to it. Use a word processor to retrieve the file and store modification in a non-document mode. Failure to do so may result in improper operation of the Cal-Bench system. Refer to the insert of the Color.CFG file for line descriptions.

Printer.CFG File

Printer.CFG file contains the filename of the printer driver library and the filename of the printer driver. The printer driver library is Gxprint.GXL, line 01 in the Printer.CFG file. A text listing of the printer drivers available in the library are in Gxprinter.TXT file. You can use a word processor to view the Gxprinter.TXT file to find the name of the printer driver for your printer. The name of the printer driver must be placed on line 02 in the Printer.CFG file.

Each line of data occupies 30 spaces before the semicolon. The 30 spaces must be maintained for each line of the Printer.CFG file for proper operation. Three lines of the header must be included in the file. The software skips the first three lines then reads the printer driver library name followed by the printer driver name.

Make a backup file of the Printer.CFG file before making any changes to it. Use a word processor to retrieve the file and store modification in a non-document mode. Failure to do so may result in improper operation of the Cal-Bench system.

Remove this page and insert:

Color.CFG file printout

&

Printer.CFG file print out

Backside of

Remove this page and insert:

Color.CFG file printout

&

Printer.CFG file print out

Calibration Report Example

This standard calibration report is produced by the Cal-Bench software program.

Cal-Bench Serial Number 1240. Rev 7, 18.03 Calibration Data

Sierra Instruments, Inc.
5 Harris Court, Monterey, CA 93940

Test Date: 4/18/96 Print Date: 4/18/96

DeviceUnder Test

Description: Acme Corp.
Model Number: 820-L-2
Serial Number: 12345
Range: 0-1000
Bypass: N/A

Ambient Conditions

Gas Temperature: 70.4 Degrees F
Room Temperature: 72.3 Degrees F
Ambient Pressure: 29.89 In Hg
Back Pressure: 1.650 In H2O
Relative Humidity: 43.00 Percent

Master

Serial Number: None
Full Scale Flow: 1000 SCCM

STP

Temperature: 70.0 Degrees F
Pressure: 29.92 In Hg

--------GAS DATA-------

%	Density	N	Cp	Name
100.00	1.250	1.000	0.248	Nitrogen, N2

Test Gas: Nitrogen, N2
Calculated k Factor is : 1.000

--------DATA--------
Full Scale Flow:

Voltage VDC	Indicated Flow SCCM	Actual Flow SCCM	Error % Full Scale	Error % Reading
0.000	0.000	0.000	0.0	0.0
1.250	250.000	250.000	0.0	0.0
2.500	500.000	500.000	0.0	0.0
3.750	750.000	750.000	0.0	0.0
5.000	1000.000	1000.000	0.0	0.0

The equations below represent the transfer function of the raw transducer:

FLOW, SCCM = 2.00000000000000E+0002 X + 0.00000000000000E+0000

VOLTS = 5.00000000000256E-0003 Y + –1.27897692436818E-0012

-----DEVICE INFORMATION-----

Vacuum Test:	5 x 10^ – 9 Atm cc/sec (He)
Fittings:	Sensor mV at Full Scale:
Inlet Pressure:	Outlet Pressure:
Meter O-Rings:	Valve Seat Material:
Cal-Bench Asset Number:	DVM Asset Number:

-----COMMENTS -----

TEST #1 FOR ACME CORP
TEST FOR FINAL CAL/QC
TEST COMPLETE

Calibration Technician:______________________________Date: ____________________

QC Technician: ___________________________________Date: _____________________

The calibration standards used in this procedure are traceable to NIST or applicable international standards.

This instrument has been calibrated in accordance with the provisions of ANSI/NCSL Z540 and ISO/IEC Guide 25.

Calibration Due Dates are listed below:

- D/A and A/D converters: _________
- Cal-Bench System: __________
- System Clock: ___________
- Glass Tube Diameters: ____________

Custom.CFG File

The Custom.CFG file allows you to add these nine items of information to the calibration report:

- Vacuum Test 5 x 10^–9 Atm cc/sec (He)
- Fittings
- Sensor mV at Full Scale
- Inlet Pressure
- Outlet Pressure
- Filter O-Rings
- Valve Seat material
- Cal-Bench Asset Number
- DVM Asset Number

The information that is entered is not saved in the records and is strictly done on the fly. If you want to customize the file, enter the information BEFORE printing the calibration report.

The Custom.CFG file allows you to ask for whatever additional information you want to appear on the report. The Custom.CFG file can be changed to suit your particular needs. The first two lines go together where the first line will prompt you for input and the second line will be concatenated to the data entered. Each of the following lines are individualized. Each line is used as a description for the data entered and the input information will be printed following the description. These descriptions can be changed to suit your particular needs. Always make a backup of this file before you alter the information in it. You must use an ASCII text editor or word processor in non-document mode when changing the contents of this file.

CAL-BENCH REPORT CONFIGURATION FILE

58	; (00-I)	Lines Per Page
true	; (01-B)	Customer Data Field
true	; (02-B)	Master Serial # and Full Scale Flow Field
true	; (03-B)	Gas Data Table
false	; (04-B)	Equation Field
true	; (05-B)	Comment Field
false	; (06-B)	NIST Test # Field
true	; (07-B)	Accuracy Field
false	; (08-B)	Rotameter non linear warning
Device Under Test	; (09-S)	Title: Device Under Test
Ambient Conditions	; (10-S)	Title: Ambient Conditions
Master	; (11-S)	Title: Master
STP	; (12-S)	Title: STP
GAS DATA	; (13-S)	Title: GAS DATA
DATA	; (14-S)	Title: DATA
Device Information	; (15-S)	Title: Device Information
COMMENTS	; (16-S)	Title: COMMENTS
Cal Technician	; (17-S)	Title: Calibration Technician
Q.C. Technician	; (18-S)	Title: QC Technician
Flowmeter	; (19-S)	Name of Rotameter, could be Flowmeter
Serial Number	; (20-S)	Name of master serial number
false	; (21-B)	Enable Test Equipment Report
Test Equipment	; (22-S)	Title: Test Equipment
Cal Bench Asset No.	; (23-S)	Name of Item 1 Under Test Equipment
Barometer Asset No.	; (24-S)	Name of Item 2 Under Test Equipment
%RH Meter Asset No.	; (25-S)	Name of Item 3 Under Test Equipment
Thermometer Asset No.	; (26-S)	Name of Item 4 Under Test Equipment
DVM(s) Asset No.	; (27-S)	Name of Item 5 Under Test Equipment

----

HELP: I – Integer Data
B – Boolean Data (TRUE or FALSE).
S – String Data (i.e. Device Under Test).

Report.CFG File

The Report.CFG file allows you to configure the calibration report to the particular needs of your calibration lab. The Boolean data turns on or off the fields within the calibration report. A “true” will enable the field and a “false” will disable the field to appear on the print out. The Boolean data in Report.CFG initialized. The string data are the title headers you want for each category to be on the report. Each string is limited to 30 characters or spaces. Always make a backup of Report.CFG file before you change it. You can use an ASCII text editor or word processor in the non-document mode to alter the file to suit your needs.

Modifying the Gas Tables

A data base of 135 gases is included in the gas table file used in the Cal-Bench™ software. This table is very handy when calibrating thermal capillary tube mass flow meters and controllers.

If desired, the user can modify this table or add additional gases. When editing this file it is imperative that the information be stored in ASCII format using the non-document mode. The following information is listed in the gas tables. See the Mass Flow Meter Instruction Manual for more information.

Gas - name of gas
Chemical Symbol of gas
Test Gas - recommended calibration gas
Chemical Symbol for Test Gas
K factor relative to the reference gas
K factor relative to Nitrogen
Cp - Heat Capacity, Cal/g
Density, g/l
N - factor for the number of atoms in the gas molecule.

For example:

Acetylene - Gas
C2H2, Chemical formula for Acetylene
Ethylene - Test Gas
C2H4, Chemical formula for Ethylene
.973 - K factor of Acetylene relative to Ethylene
.58 - K factor of Acetylene relative to Nitrogen
.4036 - Heat Capacity (Cp)
1.162 - Density g/l
.88 - N factor

This information is contained in the gas table in the following format:

Acetylene, C2H2
Ethylene, C2H4
.973 .58 .4036 1.162 .88

Note that spaces are used as delimiters in the last line. When modifying or making your own table, it is extremely important to include every entry as described above. Omitting any information will result in a major error and force a reboot of the program.

If you wish to edit this table, it is recommended that you make a back-up of the table. You must also insert your "new gas" in alphabetical order, by gas name, if you wish to retrieve it by hitting the first letter.

Breakpoint Files

Breakpoint files are used in the Generate Mode, Final Q.C. and Transfer Standard modes of the software. They are used to establish calibration points.

The Breakpoint files can contain up to 32 calibration points. The contents of the file are integer numbers representing the percentage of the full scale of the Device Under Test. The set of points must start with 0 (zero) and be in ascending order. A typical 5 point calibration (calibrating at 0, 25, 50, 75, and 100%) will have the following Breakpoint file:

0
25
50
75
100

Calibrating at every 10 percent would give the following Breakpoint file:

0
10
20
30
40
50
60
70
80
90
100

Use a non-document word processor to write the Breakpoint files in ASCII format. Or, use the DOS command “COPY CON.” The files can have any 8 digit name followed by the extension .BRK. To have the above shown Breakpoint file calibrating at every 10%, name the file TEN.BRK.

To create a file with the breakpoints at 0, 25, 50, 75, and 100, use the DOS command “COPY CON” to create a file named TEST.BRK.

1. Go to the desired sub-directory and at the DOS prompt type:

   COPY CON: TEST.BRK

2. Press ENTER.

3. Enter the test points with one number per line followed by ENTER. Note that it is not possible to change an entry after Enter has been pressed.

   0
   25
   50
   75
   100

4. Press ENTER after entering each line.

5. When complete, press F6, then press ENTER. The file is now saved in the sub-directory you were last in. The Breakpoint files can be reviewed by going to the correct sub-directory and typing TYPE and the name of the file including the extension.

Available Breakpoint Files

BA.BRK	BB.BRK	BC.BRK	BQ.BRK
0	0	0	0
25	10	13	100
50	20	25	
75	30	38	
100	40	50	
	50	63	
	70	88	
	80	100	
	90		
	100		

BT.BRK	BU.BRK	BZ.BRK
0	0	0
40	15	12
45	35	25
50	65	37
60	100	50
70		62
100		75
		87
		100

Adding Automatic Ambient Inputs

The Cal-Bench™ system requires input of the following ambient conditions:

- Gas Temperature
- Room Temperature
- Ambient Pressure
- Back Pressure
- Relative Humidity

These inputs are automatically entered into the program with the use of the A/D and D/A board supplied with the Generate mode option of the Cal-Bench system. If you want to add an automatic sensor to your existing system, contact the factory for specific instructions and recommendations.

The software used the equation Ax^2+Bx+C to relate A/D voltage to the signal from the sensor. This information is entered in the CDDF.CFG file. When these sensors are recalibrated, you can re-enter the new calibrated values for A, B and C in the CDDF.CFG file.

The following table indicates the connections of the external device to the A/D converters via the 50 pin terminal block mounted on the side of the computer.

External Device Connections to the 50 Pin Connector		
Terminal Block Pin Number	Function	A/D Channel
1 and 2	Analog ground	N/A
3	Master MFC	0
4	Ambient Pressure	8
5	Test MFC	1
6	Room Temperature	9
7	Gas Temperature	2
8	Bell Prover Linear Encoder	10
9	Back Pressure	3
10	Bell Prover Back Pressure	11
11	% RH	4
12	Bell Prover Gas Temperature	12
13	Second Bell Prover Linear Encoder	5
14	N/A	N/A
15	Second Bell Prover Gas Temperature	6
16	N/A	N/A
17	Second Bell Prover Back Pressure	7
18	N/A	N/A

Appendix B Certificates

Appendix B includes the following items:

- Cal-Bench™ System Item List
- Cal-Bench System Certificate and component serial numbers
- Certification reports
- Mercury Material Safety Data Sheet

Cal-Bench System Item List

Customer: ____

Customer Code:____

P.O. No.:____

System Serial No.: ____________________________________

___ 1 Computer SN #____________
___ 1 Monitor SN # ______________
___ 1 Keyboard SN# ________________
___ 1 Sierra MFC SN # ______________
___ 1 Sierra MFC SN # _____________
___ 1 Sierra MFC SN # # ___________
___ 1 Tube Cabinet
___ 1 902 Control Box Assembly SN # _________
___ 1 Cal-Bench Sonar Box Assembly SN # ___________
___ 1 Cal-Bench Program Disk
___ 1 Large Tube SN # _______
___ 1 Medium Tube SN # _______
___ 1 Small Tube SN # _________
___ 2 8' 10-Conductor Cables (CH 1 & CH 2 or Control Box Assy)
___ 1 8' 10-Conductor Cable with Silver Hirose Connector
___ 1 8' 7-Conductor Cable with Blue Hirose Connector
___ 1 8' 9-Pin Conductor Cable (with Computer)
___ 1 5” 50-Pin Ribbon Cable
___ 1 8'-Two Round Cables to 26 Pin Connector (with Computer)
___ 5 Belden Power Cords (One each – Computer, Cal Box, Sonar Box, Control Box and Barometer Box)
___ 1 8’ 6-Conductor cable with Mini Con-X-All connector

___ 1 Small Uhem 1000 Piston & Target
___ 1 Medium Piston & Target
___ 1 Large Piston & Target
___ 1 Set of O-Rings (1 5-428; 1 2-139; 1 2-116)
___ 1 Hold Down Nut for Large Tube
___ 1 Hold Down Nut for Medium Tube
___ 1 Hold Down Nut for Small Tube
___ 1 Horn for Small Tube
___ 1 Plexiglass Window
___ 1 Sensor Cleaning Stylet Kit
___ 1 Mercury Syringe
___ 1 Cal-Bench™ Instruction Manual
___ 1 Barometer Model Setra 270 SN # __________
___ 1 RH/tempature Indicator Model SN #____________
___ 1 Mass Flow Meter & Controller Instruction Manual
___ 1 Set of Manuals for Computer

OPTIONS:

____ 1 220 VAC to 110 VAC Converter (For 220 VAC Cal-Bench)
____ 1 Graphics Printer Model Epson FX-850 SN ________
____ 1 Parallel Cable for Printer
____ Bell Prover Option

COMMENTS: ____

The Cal-Bench system has auto inputs for room temperature, gas temperature and back pressure, % RH and ambient pressure. The barometer is in blue box, room temperature and % RH indicators are located in the top of tube cabinet.

Sierra Instruments, Inc.
Hereby certifies that Cal-Bench™ system
Serial Number____________________
comprised of the following sub-systems:

Part Description	**Serial Number**
Data Acquisition Board	
Large Tube	
Medium Tube	
Small Tube	
Bell Prover Option	
QProver Option	
Ambient Pressure Transducer	
Gas Temperature/Gas Back Pressure Transducer	
Sonar Box	
Ambient Temperature/Relative Humidity Transducer	
902 Control Box	

is traceable to NIST upon shipping from our dock when used in accordance with the guidelines of the Cal-Bench Instruction Manual.

Automated systems require that the supplied CDDF.CFG file remain unaltered and manual systems require that all of the above devices be maintained in accordance with the manufacturer's guidelines and meet accuracy levels required by the Cal-Bench System Error Analysis.

Certificate of Calibration Cal-Bench Tube Diameters

Customer:____Customer Code:___________

Date:_______________P.O. No.:________________Cal-Bench System S/N___________

Ambient Temp.:_________ Ambient Pressure:_________ Relative Humidity:_________%

Tube Serial No:______________Cal-Bench Tube Size_____Small_____Medium_____Large

Suggested Calibration Interval: 24 months Due Date:________________________

---Test Equipment Specs---
Edmunds Model E5809000 Accu-Setter Air Gauge S/N234068D

Max. Ring:____________NIST Test No.: 731/231140-88 + Gauge Reading:_________
Min. Ring:____________NIST Test No.: 731/231140-88 – Gauge Reading__________
Gauge Range:__________ Ring Gauge Reading:______
Plug Size___0.5000___1.7500___5.6580

The 24 reading below are taken at one inch intervals from the bottom of the glass tube. The readings are the direct indications from the air gauge master gauge indicator.

Inches from bottom	Reading	Inches from bottom	Reading	Inches from bottom	Reading
0		8		16	
1		9		17	
2		10		18	
3		11		19	
4		12		20	
5		3		21	
6		14		22	
7		15		23	
Total 1:		Total 2:		Total 3:	

Mean Value = $\frac{\text{Total 1 + Total 2 + Total 3}}{24}$ = $\frac{\_\_\_\_ + \_\_\_\_ + \_\_\_\_}{24}$ = ______†______

Mean Diameter (inches) = Plug Size + (mean value)

Mean Diameter (inches) = ____________ + _________________ = _____________ in

Mean Diameter (cm) = Mean Diameter (inches) x 2.54 = ____________________cm

Tube K-factor, K = 3.14/4 (Mean Diameter [cm])^2 = _________________________cc/cm

† Note: The mean value may be a negative number. The equipment used to measure this tube has been calibrated with master rings which were certified by National Institute of Standards and Technology, Washington, DC. Our calibration system is in compliance with ANSI/NCSL Z540 and ISO/IEC Guide 25.

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Test equipment certification reports (7)

Mercury MSDS

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Test equipment certification reports (7)

Mercury MSDS

Appendix C Control Box Assembly

Appendix C describes the features and operation of the 902 Control Box Assembly, an important component of your Cal-Bench system.

Features of the 902 Control Box

With the control box, one or two independent flow meters or controllers can be operated simultaneously. Linear operation with LCD readout is standard.

The back panel connectors provide outputs of 0-5 VDC and 4-20 mA and are 0-100% analogs of the flow range. Both voltage and current outputs are simultaneously available.

Flow setpoint for flow controllers is from either the front panel adjustment potentiometers or a remote source via the back panel I/O interface.

The power supply is a linear (non-switching) laboratory quality unit capable of easily supplying power to 2 channels simultaneously.

On the control box, the rotary switch labeled Channel Select determines which channel is displayed. The flow value is normally read from the LCD Display. Readout is in percentage, 0 - 100%.

The control box toggles between flow reading and flow setpoint by the switch labeled "SET/READ." When in the READ mode, the display shows flow value as above. When in the SET mode, the display shows the current setpoint value in the same units as the "READ" mode.

AC Power Line and Fuse

The AC power line connector (or power entry module) is located on the back panel. A cordset is supplied with the control box and is compatible with wall outlets in the USA. Make sure the control box is wired for the proper power mains voltage, either 115 VAC, 60 Hz or 230 VAC, 50/60 Hz, as indicated on the label. If you want to change the receptacle configuration, you may use any standard CEEE 22 cordset.

The fuse is in the panel mount fuse holder next to the AC power connector. To remove the fuse, turn the front panel power switch OFF then remove the cordset from the back panel power connector. With the cordset removed, push and turn fuse knob counter-clockwise to remove. The fuse is an AGC type 3 amp rating. Replacement fuses are widely available.

20-Pin Transducer Connector

The back panel has two 20-pin headers labeled channel 1 and channel 2. Channel 1 is the master flow controller. Channel 2 is the Device Under Test flow controller or meter. Normally, cables are prewired and the entire system is set-up at the factory. See page C-3 for pin assignments.

Caution

Do not plug a transducer into the wrong channel. Flow values may be extremely inaccurate and/or damage may result to system electronics and transducer.

26-Pin I/O Connector

The 26-pin I/O Connector on the back panel provides access to many of the control box functions such as flow outputs, valve override and monitoring, etc. The following section covers these functions in detail. Pin assignments are shown on page C-4.

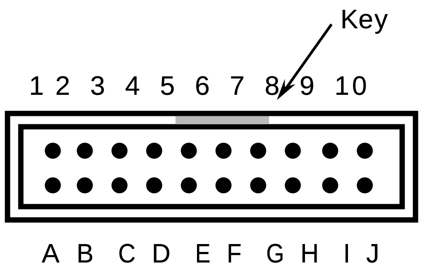
Flow Value Output 0-5 VDC and 4-20 mA

The 26-pin I/O connector provides two analog outputs for each channel. One provides a 0-5 VDC LINEAR analog of the flow value referred to common. The other supplies a 4-20 mA LINEAR analog of the flow value referred to +15 VDC. Both outputs are always present for all channels.

Automatic/Manual Setpoint Selection (Controllers)

There are two switches on the front panel, channel 1 and channel 2. For each channel they determine whether the 0-5 VDC setpoint input comes from the front panel pots (MANUAL) or from the 26-pin I/O connector (AUTOMATIC). These switches are easily changed in the field simply by moving them from one position to the other position. The system will not function as a control box for mass flow controllers when the switches are in the manual position.

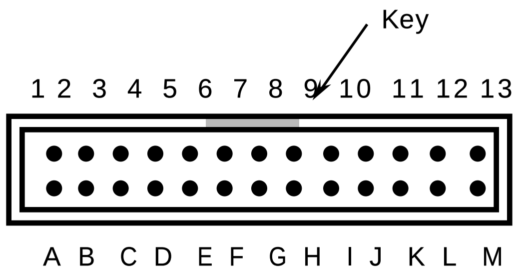
20-Pin Transducer Connector Assignments



(view of connector from back of enclosure)

Pin No.	Function	Pin No.	Function
1	Setpoint output to controllers	A	Chassis ground
2	Common	B	Common
3	Common	C	0-5 volt signal from transducer
4	Valve test point (avail. I/O connector)	D	+15 VDC supply from system electronics to transducers
5	RED connection (Factory Use Only)	E	BLACK connection (Factory Use Only)
6	–15 VDC supply from System Electronics to transducers	F	No connection
7	No connection	G	No connection
8	High Alarm Output (avail. I/O connector)	H	+15VDC supply from System Electronics to transducers
9	Low alarm output (avail. I/O connector)	I	4-20 mA signal from trans- ducer
10	Valve Off (avail. I/O connector)	J	Common

26-Pin I/O Connector Assignments



(view of connector from back of enclosure)

Pin No.	Function	Pin No.	Function
1	Channel 1, 0-5 volt linear output	A	Common
2	Channel 2, 0-5 volt linear output	B	Common
3	Channel 1, automatic set-point input	C	Common
4	Channel 2, automatic set-point input	D	Common
5	Channel 1, 4-20 mA linear output	E	Channel 1 valve test point
6	Channel 2, 4-20 mA linear output	F	Channel 2 valve test point
7	+15 VDC power supply	G	–15 power supply
8	+15 VDC power supply	H	–15 power supply
9	Common	I	Channel 2 valve off input
10	Common	J	Channel 2 totalizer (pulse train output)
11	Channel 1 totalizer (pulse train output)	K	Channel 2 totalizer (pulse train output)
12	Channel 1 high alarm output (open collector)	L	Channel 1 low alarm output
13	Channel 2 high alarm output	M	Channel 2 low alarm output