SuperFlow
DYNAMOMETERS & FLOWBENCHES
A Division of Power Test, Inc.

Operator Manual

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SF-260

Original Instructions

www.superflow.com

SF-260 FLOWBENCH

Trademark Notices

Please keep this manual for future reference.

This manual is intended to assist operating personnel in becoming familiar with the product and as guidance in ordering necessary parts inclusive of SuperFlow's warranty requirements. Maximum operating efficiency and life of any SuperFlow product will be attained through complete understanding of the instructions and recommendations contained within this manual.

WARNING	IMPORTANT
Services performed beyond preventive maintenance by personnel other than SuperFlow Service Technicians on any SuperFlow products during the warranty period may void the warranty.	**When available, please include the model number and serial number of the product in any correspondence.**

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SuperFlow DYNAMOMETERS & FLOWBENCHES A Division of Power Test, Inc.

1.0 Introduction

1.1 About This Manual

This manual is provided as a reference to explain the operation of the SuperFlow SF-260 as used on any engine test system.

An electronic PDF copy of this manual is provided on the thumb-drive sent with the SuperFlow system.

IMPORTANT

Please read the complete manual in detail, prior to operating the machine. Contact SuperFlow immediately if you experience problems to avoid any warranty issues.

1.2 Target Audience

This manual is intended to be used by skilled operators proficient in the operation of the SuperFlow SF-260 flowbench.

1.3 Product Features

- Rugged construction to withstand harsh shop environments
- Castors allow for easy movement
- Bi-directional flow (intake and exhaust modes)
- Air bypass valve to provide motor cooling at low flow levels
- Automatically calculates and shows flow on the Liquid Crystal Display (LCD)
- Automatically regulates test pressure or flow
- External velocity probe and swirl meter inputs
- Communicates with computers equipped with optional airflow analysis software

2.0 Safety Guidelines

Safety is the most important consideration when operating any machine. Operators and service personnel should read this manual and become familiar with its content before attempting to operate this machine or to perform service or maintenance to it. Familiarization with this manual will minimize the possibility of accidents or injuries. Although the procedures covered in this manual have proven safe in use, SuperFlow assumes no responsibility for personal injury or damage to equipment resulting from its applications. All operators must be aware that there are several hazards present to anyone in the test cell. Some of these hazards are:

- Hearing damage due to high noise levels
- Electrical shock
- Exposure to rotating parts

Always follow basic safety precautions when using this product to reduce risk of injury or damage to equipment.

- Only authorized personnel knowledgable of the operation of the flowbench should have access to the equipment.
- Read and understand all instructions in the user guides.
- Keep the air ducts free of dust or dirt.
- Keep loose material away from the inlet and exhaust ducts.
- Always wear eye and hearing protection whenever operating.
- Use only the proper electrical sources. Ensure circuit breakers are easily accessible and have the proper rating.
- Observe all warnings and instructions marked on the product.
- Provide fire extinguishers that are rated for electrical and oils.
- Provide adequate lighting in the test area.
- Refer all service questions to qualified personnel.
- Do not remove any safety guards while the machine is in operation, and be sure the safety guards are correctly mounted before operating the device.
- Disconnect the external power switch before opening the rear panel of the device.
- Replace the power cable if it is damaged.
- Do not store flammable materials in the vicinity of the flowbench.
- Follow all local construction codes.

These are general guidelines for working with any machine. It is often helpful to prepare a safety checklist that is distributed to all personnel who enter the test cell. Proper safety is achieved through reinforcement and discipline.

2.0 Safety Guidelines

This manual places safety concerns into four categories, they are:

⚠ DANGER

This is the highest level statement. Failure to follow the listed instructions will most likely result in severe injury or death.

⚠ CAUTION

The statements used with this level of warning deal with a safe operating procedure. If they are ignored the possibility of equipment damage or personal injury may exist.

⚠ WARNING

This is a statement of serious hazard. Failure to follow the listed instructions could place the individual at risk of serious injury or death.

IMPORTANT

IMPORTANT indicates precautions relating to operation or usage of the machine or highlights important information on a page.

The following universal warning decals can be found in the appropriate locations on your equipment. A description of each warning decal is provided below. In addition, these symbols will appear throughout the manual in sections where these hazards may be encountered.

Refer to Manual

- Read and understand manual before operation.
- Failure to understand manual may result in personal injury and/or death.

Wear Eye and Hearing Protection

Rotating components could cause flying debris.

Noise levels can reach up to 85 decibels (dB) or above during machine operation.

Warning

- General warning label.
- Indicates an imminent hazard.

Entanglement Hazard

- Keep hands and arms free of rotating shaft.
- Ensure system has stopped and starting has been disabled prior to servicing.
- Do not operate without all guards and covers in place.

Electric Shock

- Exercise caution when working on or nearby. Make certain that power has been disconnected and all residual voltage has been taken under consideration. Unqualified personnel should never attempt electrical work.

Contact SuperFlow if you have any questions about the safe operations of our equipment and for service and advice.

2.0 Safety Guidelines

2.1 During Operation

DANGER

DO NOT remove any safety guards while the machine is in operation, and be sure the safety guards are correctly mounted before operating the device.

WARNING

WEAR EYE and HEARING PROTECTION. Proper eye and hearing protection should be worn at all times when the equipment is operating.

WARNING

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts.

- **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).**
- **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around Printed Circuit Boards (PCBs).**
- **Do not touch the components or conductors on a PCB with your hands or with conductive devices.**

WARNING

- **Inspect the equipment monthly to ensure that there are no broken or worn parts which could cause injury to personnel or damage to the equipment.**
- **Only qualified operators and maintenance personnel should perform the procedures covered in this manual.**

CAUTION

- **Keep the air ducts free of dust or dirt.**
- **Keep loose material away from the inlet and exhaust ducts.**

2.0 Safety Guidelines

2.2 Lockout/Tagout Procedures

⚠ WARNING

When working with electrical or electronic controls, make sure that the power source has been locked out and tagged out according to OSHA regulations and approved local electrical codes.

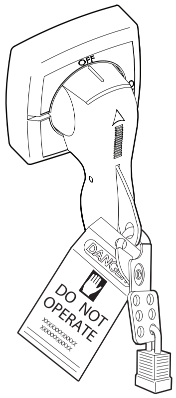


Figure 2.1: Lockout/Tagout

The Occupational Safety and Health Administration (OSHA) requires, in addition to posting safety warnings and barricading the work area (including, but not limited to, control room and testing bay), that the power supply has been locked in the OFF position or disconnected. It is mandatory that an approved lockout device is utilized. An example of a lockout device is illustrated in "Figure 2.1: Lockout/Tagout". The proper lockout procedure requires that the person responsible for the repairs is the only person who has the ability to remove the lockout device.

In addition to the lockout device, it is also a requirement to tag the power control in a manner that will clearly note that repairs are under way and state who is responsible for the lockout condition. Tagout devices have to be constructed and printed so that exposure to weather conditions, or wet and damp locations, will not cause the tag to deteriorate or become unreadable.

Power Test does not recommend any particular lockout device, but recommends the utilization of an OSHA approved device (refer to OSHA regulation 1910.147). Power Test also recommends the review and implementation of an entire safety program for the Control of Hazardous Energy (Lockout/Tagout). These regulations are available through OSHA publication 3120.

3.0 System Overview

3.1 Overview

SuperFlow flowbenches are designed to measure the airflow resistance of engine cylinder heads, intake manifolds, or other devices as assemblies or separate units. For intake flow testing, air is drawn in through the test device into the machine through the air pump and exits through the vents at the rear of the flowbench. For exhaust flow testing, the path of the airflow is reversed.

SF-260 each have four motors that function as air pumps. Two motors are used in intake mode and the other two for exhaust mode. To select the mode, use the switch on the front control panel to select the motors used and flow control valves to set the flow direction.

FlowCom™ is a self-contained, microprocessor-based flowbench computer. It shows the test pressure and flow rate on an easy-to-read Liquid Crystal Display (LCD). When used with a motor controller, FlowCom automatically controls test pressure or flow based on a keypad input. The data results can be frozen at each test point with the FlowCom keypad or with a foot-operated push-button switch (optional) while hand recording the data. When used with Port Flow Analyzer™ software from Performance Trends, FlowCom graphically displays flow data (in English or metric units) in real time.

3.1.1 Feature Highlights

- Rugged construction to withstand harsh shop environments
- Bi-directional flow (intake and exhaust modes) allow operators to test in intake and exhaust mode without having to move the test device
- Easy to operate
- Includes FlowCom
  - FlowCom automatically calculates and shows flow and test pressure on the FlowCom LCD
  - FlowCom Automatically regulates test pressure or flow
  - FlowCom allows for external velocity probe input
  - FlowCom can communicate with computers equipped with optional airflow analysis software

3.1.2 Options

- **Velocity Probes:** Velocity probes can be connected to the FlowCom to display air speed or velocity percent.
- **Adapters and Fixtures:** SuperFlow offers a wide assortment of adapters and fixtures for mounting your test device to the flowbench.
- **Flowbench Software:** All data can be simultaneously transmitted in real time to a computer through a serial port or USB connection. SuperFlow's WinDyn™ software or Performance Trends' Port Flow Analyzer™ software graphically displays flow data (in English or metric units) in real time and records data for later analysis.

3.1.3 Calibration

Every SuperFlow flowbench is calibrated and tested before it leaves the factory. Each bench comes with its own calibration sheet to ensure you generate the most accurate test data. For flowbenches equipped with FlowCom, the calibration is entered directly into the flow computer. The bench can be re-calibrated using test orifice plates available from SuperFlow Customer Service.

3.0 System Overview

3.1.4 Special Applications Using a SuperFlow Flowbench

Most SuperFlow flowbenches are used to measure airflow through cylinder heads (intake and exhaust), manifolds, throttle bodies, carburetors, and other normal components.

But what can you measure on a SuperFlow flowbench? The answer is just about anything you can mount on the bench. Some manufacturers use the bench as a Quality Control (QC) process to quantify various catalyst materials. Other applications include mufflers and air filters. The aerospace industry uses the flowbench to maintain QC on parts for various gas turbine components.

What is the largest diameter part tested on a SuperFlow bench? Over 18 inches in diameter and 6 feet tall. The component is for a very large gas turbine that drives a stationary electrical power generator.

Odd applications? How about natural gas control valves that control the fuel for gigantic shipboard engines? How large? A 10,000-hp valve is considered small.

Small applications? The smallest known application is used to set the idle opening in throttle bodies where the target is 3.5 cfm at 25"$H_2$0.

3.2 Specifications

Capacity

- 200 cfm ± 10% @ 10” test pressure (94 l/s ± 10% @ 25 cm)

Instrumentation

- FlowCom

Accuracy

- Flow Measurement: ± 1% of full scale reading (in normal operating ranges)
- Test Pressure: ±0.05” H_2O (±0.13 cm)

Repeatability

- ± 0.5% of full scale reading

Temperature Measurements

- Thermistor probe(s): –112 to + 248°F ±0.5° (–80 to +120°C ±0.3°)

Weight

- 100 lbs. (46 Kg)

Dimensions

- 27"L x 20"W x 36"H (69 x 51 x 91 cm)

Shipping Weight

- 115 lbs. (53 Kg)

Shipping Dimensions

- 33"L x 23"W x 38”H (84 x 59 x 97 cm)

Controls

- Intake/exhaust flow direction (two-position switching valve)
- Intake flow (variable position orifice)
- Exhaust flow (variable position orifice)
- Air supply on/off (toggle switch)
- Motor on/off (toggle switch)

Safety Features

- Automatic over-temperature protection on the motors

Power Requirements

- 220–240 VAC, 12A, 50/60 Hz, single phase

3.0 System Overview

3.3 FlowCom

The Flow Computer (FlowCom) is a handheld or panel-mountable, microprocessor-based flowbench computer. It automatically gauges test pressure and temperature to show corrected flow on an easy-to-read LCD. When combined with SuperFlow's motor controller, FlowCom automatically controls test pressure or flow based on keypad input. When used with Port Flow Analyzer™ software from Performance Trends, FlowCom graphically displays flow data (in English or metric units) in real time.

Figure 3.1: FlowCom

A FlowCom used with the flowbench will display the test pressure and flow rate when the FlowCom is set to the same range as the flowbench (providing the calibration values for the flowbench were properly entered into the FlowCom). The data results can be frozen at each test point by pressing a button on the FlowCom or using a foot-operated, push-button switch (not included) while manually recording the data.

When used with a motor controller, FlowCom automatically regulates the test pressure or flow based on the keypad input. With the flowbench range, direction, and control valves set properly, FlowCom controls the motor speed to maintain the test pressure to the entered valve and displays the flow rate in cubic feet per minute (cfm), liters per second (l/s), or cubic meters per hour (cmh). The FlowCom can also control to flow rate and display the test pressure.

The front panel on the FlowCom is the operator's interface to the flowbench. The enclosure houses the flow computer circuitry along with pressure ports for the flow pressure (P1), test pressure (P2), and velocity probes (P3). The FlowCom also has a receptacle for a foot switch, an input connection for a swirl meter (or other analog device), connections for temperature probes, and a power connection. Communication with computer software is through a serial port or Universal Serial Bus (USB) port.

The FlowCom display and keypad operation are described in Chapter "5.2 FlowCom Operation" on page 28.

3.4 Options and Accessories

3.4.1 Test Orifice Plate

A test orifice plate with a 0.312" (7.9 mm) diameter and a 1.875" (47.6 mm) diameter hole is included with each flowbench.

3.4.2 Adapters and Fixtures

SuperFlow offers a wide assortment of adapters and fixtures for mounting your test device to the flowbench.

Contact SuperFlow Sales or Customer Service to find out what is available for your application.

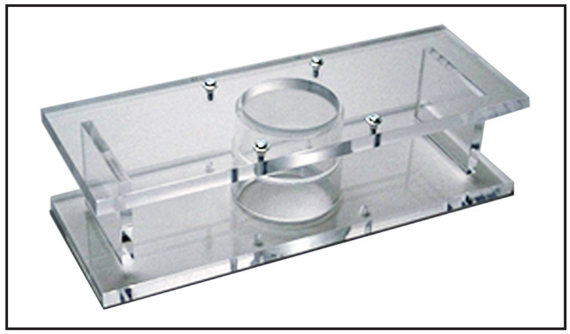


Figure 3.2: Adapter

3.4.3 Velocity Probes

The velocity probe (or Pitot Tube) is a pressure-measuring instrument that was originally designed to measure fluid velocities. The probes are now commonly used to measure the airspeed of an aircraft.

The basic Pitot tube consists of a tube pointing directly into the airflow. As this tube traps the air, pressure can be measured as the moving air is brought to rest. This pressure is the stagnation pressure of the air, also known as the total pressure, or sometimes (particularly in aviation circles) the pitot pressure.

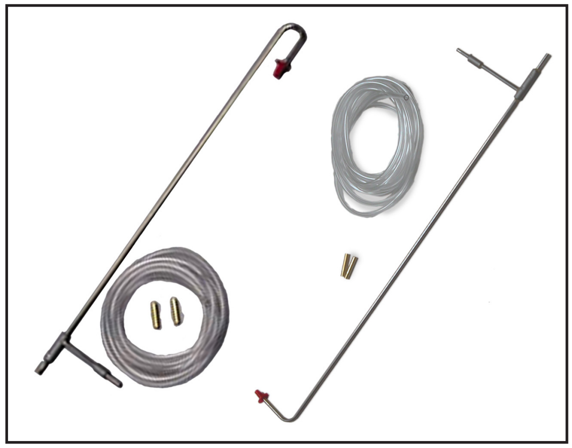


Figure 3.3: Velocity Probes

The SuperFlow velocity probe is a tube within a tube. The impact port (stagnation port or point) is the central tube. The static ports are tiny holes around the circumference of the outer tube. The differential pressure between these two port configurations allow a measurement of local velocity. When used with FlowCom, the velocity can be measured as a percentage of total velocity or as a speed (feet per second or meters per second).

3.4.4 Flowbench Software

Data from FlowCom can be simultaneously transmitted in real time to a computer through a serial port connection. Performance Trends' Port Flow Analyzer™ software graphically displays flow data (in English or metric units) in real time and records data for later analysis and printing.

4.0 Installation

4.1 Installation

4.1.1 Room Requirements

SuperFlow flowbenches should be placed in a relatively open area, free from loose debris such as metal filings or chips from machining tools. The flowbench, in essence, is a giant vacuum cleaner that will ingest rags, papers, and anything nearby that is not secured.

The flowbench should be placed on a hard, flat surface and spaced approximately 6 inches (15.2 cm) on all sides from any equipment or walls. Never place the flowbench on a soft surface such as cloth or foam. The top the flowbench must have clearance so the air flow ports are clear.

If the flowbench is in a small room and the exhaust of the bench is also into the same room, after a while it may heat the area. Thus, a method of air extraction from the small space is probably more comfortable for the operators.

It is not necessary to condition the air for temperature or humidity other than for human comfort.

4.1.2 Unpacking

WARNING

HEAVY OBJECT.
Approx. 100 Lbs. (46 Kg). Use lifting aids and/or proper lifting techniques.

The flowbench is usually shipped in a carton laid over on its back.

1. Carefully remove the flowbench from its shipping carton.
2. Place the flowbench on a level, hard table top.
3. Check carefully for any damage.
4. Make sure the on/off switch on the flowbench panel is in the **off** position, and plug the flowbench power cord into the receptacle on the rear panel.

NOTE: DO NOT plug into a power source at this time.

5. Open any accompanying boxes and verify the condition of the contents. These boxes contain accessories and options provided with the flowbench.
   - Standard options included with all flowbenches
     - Promotional package with decals and stickers
     - Rubber stoppers secured to the upper orifice plate with a short cord (five (5) for the SF-260)
     - Test orifice plate attached to the flowbench base plate with a rubber stopper for the large opening.
     - Calibration sheet mounted on the flowbench
   - SF-260
     - Flow Computer (FlowCom) mounted on the front panel
     - FlowCom motor controller w/power cord
     - Temperature sensors (2) mounted on the flowbench
     - Cable, 10 ft., Universal Serial Bus (USB) printer
     - Cable, 7 ft., Category 5 (Cat-5)
     - RJ-45 to DB-9 adapter

4.0 Installation

4.1.3 Setup Instructions

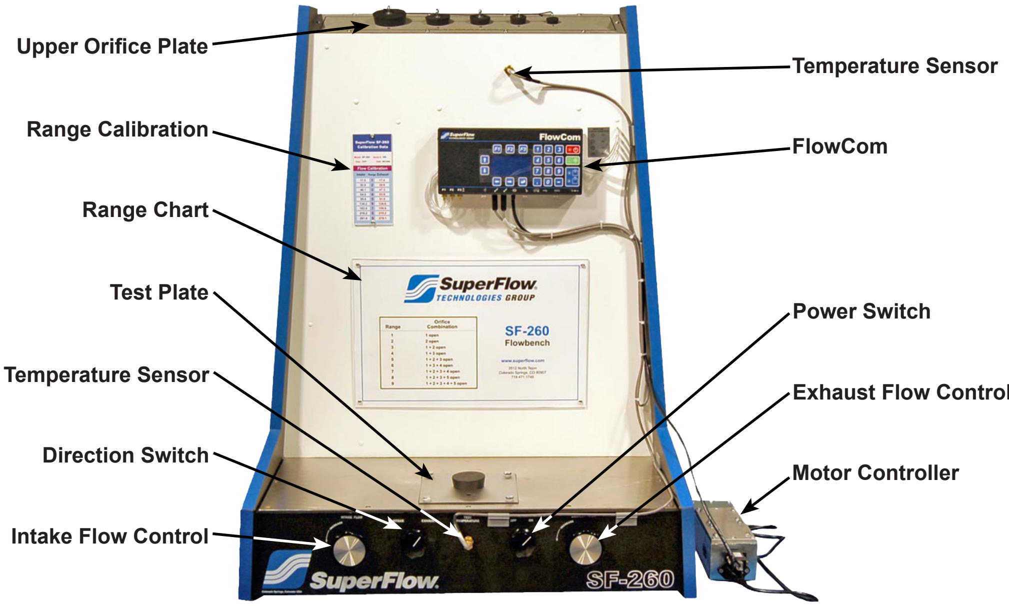


Figure 4.1: SF-260

Connect and mount the FlowCom unit provided with the flowbench according to the following procedure.

NOTE: If desired, the FlowCom can be positioned off the flowbench on a table or counter top stand next to the flowbench. Use longer hoses as necessary to reach.

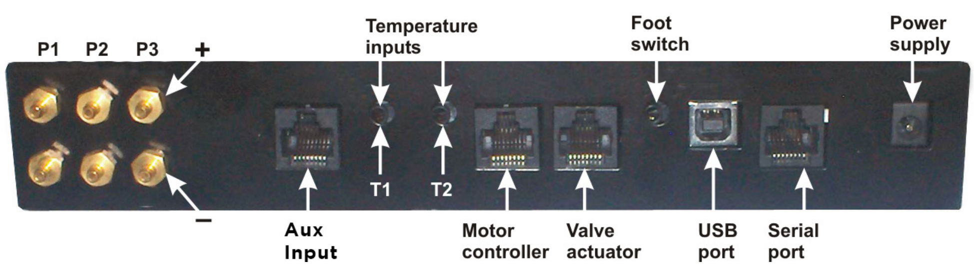


Figure 4.2: FlowCom Connections

1. Carefully unwrap the FlowCom and all accessories.
2. Place the FlowCom into position as shown in "Figure 4.1: SF-260" using the supplied Velcro™ strips.
3. Attach the clear plastic hoses between the brass tubes on the flowbench and the P1/P2 tube connections on the FlowCom as shown on the label attached to the flowbench front panel (P1+ to P1+, P1– to P1–, etc).
    - Route the hoses behind the FlowCom.
4. If not already installed, install the temperature sensors into the provided holes at the top and bottom of the flowbench as shown in "Figure 4.1: SF-260".

5. Connect the temperature sensors to the temperature inputs on the FlowCom bottom panel (see "Figure 4.2: FlowCom Connections"). It does not matter which input is used for the sensors because FlowCom uses the difference between the two readings.
6. Connect FlowCom to a power source. Power is supplied by the motor controller.
   - Place the motor controller in a convenient location close to the flowbench.
   - Insert the RJ-45 to DB-9 adapter into the connector on the motor controller.
   - Connect the Cat-5 cable between the adapter and the motor controller port on the FlowCom bottom panel (see "Figure 4.2: FlowCom Connections").
   - Locate the short power extension cable supplied by SuperFlow. Plug one end into the flowbench power plug and the other end into the motor controller. The regular power cord will plug into the other end of the motor controller.
7. Route the temperature sensor cables and the motor controller cable along the side of the flowbench front panel and secure with the provided clips.
8. Connect the power cord into a suitable, circuit-protected power source.

4.1.3 Electrical

The flowbench is wired for single-phase 240VAC power with a ground connection. For U.S. domestic models, a neutral connection is not used.

A power distribution box or outlet with a master disconnect switch should be located near the flowbench. The power source must be protected with the appropriate sized fuse or circuit breaker.

WARNING

Before connecting power to the flowbench, be sure the supply voltage and current rating match specifications for use with the flowbench, and ensure the circuit is adequately protected. If the flowbench is not wired properly, the motors will fail prematurely.

Power Requirements

- 220–240 VAC, 12A, 50/60 Hz, single phase

NOTE: If 240-VAC power is not available, 220 VAC is acceptable. The capacity of the SuperFlow flowbench is proportional to the line voltage. At voltages below 240 VAC, the maximum flow capacity will be less than normal. This has no effect on the accuracy.

DO NOT assume the electrical receptacle is correctly wired. Use a voltmeter to be certain that the voltage is 220 to 240 AC at the supply source and the ground is correctly connected to earth. This is standard, single-phase wiring.

4.0 Installation

4.2 Operational Check

Each flowbench is supplied with a test plate that verifies the bench is working properly and checks the flowbench calibration. The plate is 6” (15 cm) square with two punched holes (not bored); one is 1.875”(47.6 mm) in diameter and the other is 0.312” (7.9 mm) in diameter.

The two holes together would flow 232 cubic feet per meter (cfm) @ 25 in/H_2O test pressure if they were bored with straight edges. Actual testing will flow slightly different because of the rounded edge from punching the hole.

The nominal flow rate for the test plate is shown in the following table.

Table 4-1. Test Plate Nominal Flow Readings*

Mode	FlowCom	Flow Meter
Intake @ 10” H_2O	150 cfm	81%
Exhaust @ 10” H_2O	153 cfm	83%
Intake @ 8” H_2O	134 cfm	72%
Exhaust @ 8” H_2O	137 cfm	74%

* These are nominal readings. The test plate is stamped with the actual expected flow as measured at the factory.

IMPORTANT
The test orifice plate should be the only standard piece used to verify proper operation of the flowbench. Flowing this plate will be the first thing you will be asked to do if you call SuperFlow Customer Service for assistance.

Figure 4.3: Test Orifice Plate

At the top of the flowbench is the orifice plate. Rubber stoppers are attached to the side of the orifice plate with a lanyard—five for the SF-260. These rubber stoppers set the range on the flowbench.

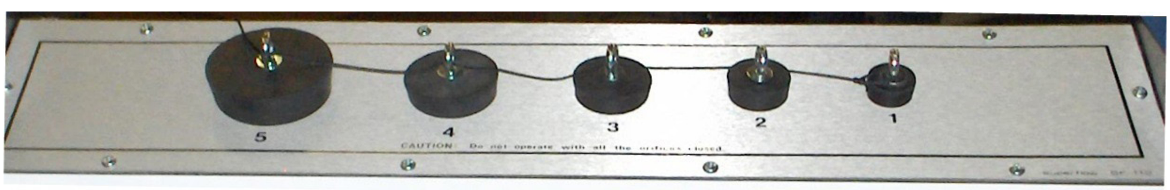


Figure 4.4: Orifice Plate

The following procedure details how to perform an operational and accuracy check using the test orifice plate. This test is not time consuming and will ensure that all test results are valid and repeatable. If the flowbench fails to meet the standards outlined in this test, the unit may have been damaged in shipment.

Contact SuperFlow Customer Service, please include your name and flowbench serial number for all inquiries.

1. Mount only the standard **Test Orifice Plate** onto the SuperFlow flowbench baseplate. Mount the plate with the label up, and ensure both holes in the test orifice plate are open.

2. Place a stopper in the **#4** hole on the orifice plate at the top of the flowbench. Leave all other holes open. Note that this is range **#8** on the flowbench.

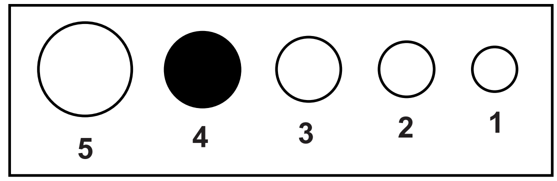


Figure 4.5: Range 8

3. Press the red **Power** button on the FlowCom panel to start it. The green Light-Emitting Diode (LED) illuminates, and the current data screen appears on the display ("Figure 4.6: FlowCom Operator Panel"). The current range setting and direction displays at the bottom of the window.

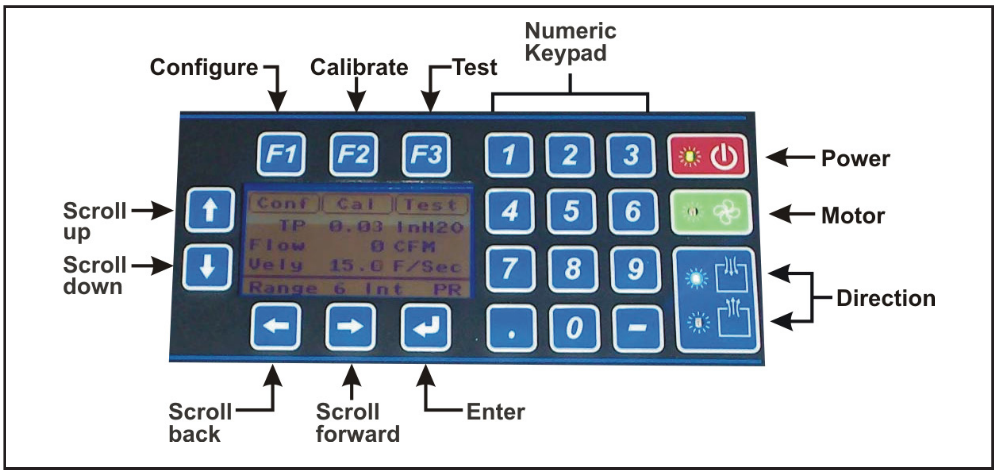
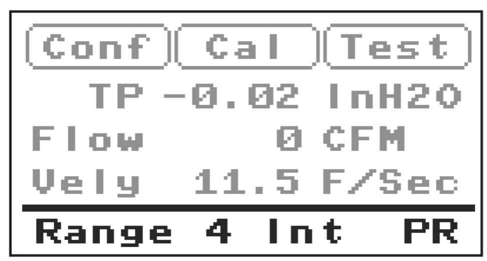


Figure 4.6: FlowCom Operator Panel

4. Press the **Direction** button to set the FlowCom to **Intake Mode**. The blue LED illuminates.

5. Use the numeric keypad to set the flowbench to range **8**. Press the number **8** button, and the range is set.



NOTE: The range and flow direction appear at the bottom of the LCD.

6. Press the **ENTER** (↵) key to display the **Test Pressure** selection window.

7. Use the numeric keypad to enter the test pressure of **10 InH$_2$O**. Press **ENTER** to set the test pressure. Then use the **UP/DOWN ARROWS** to set the units of measurement to **InH$_2$O**. Press **ENTER** to exit.

8. Set the flow units to **cfm** if not already showing this.
   - Press the **DOWN ARROW** button until the **Flow** line on the display highlights.

- Press **ENTER**.
- Press the **UP** or **DOWN ARROW** button until the **Flow Rate** channel (**9**) displays.
- Press **ENTER**.
- Press **ENTER** again to access the **Enter units of Flow Rate** screen.
- Use the **UP** or **DOWN ARROW** button to select the units of measurement (cfm, lps, or cmh).
- Press **ENTER** to exit and return to the **current data screen**.

9. Set the FlowCom leakage to zero.

The leakage must be set to zero to produce the correct readings for the test plate. The FlowCom is set accordingly prior to shipping from the factory but may have a value other than zero if the flowbench was used prior to this test. Refer to section "5.2.5 Leakage" on page 32 for instructions on setting a leakage value into the FlowCom.

10. Close (CW) the exhaust flow control knob lightly against its seat. DO NOT force the valve or it will be damaged.
11. Set the intake flow control knob to fully open (CCW).
12. Set the **mode selector switch** on the flowbench to **intake** and turn the motor switch **on**.
13. Press the green motor power switch ( ) on the FlowCom panel and allow the flowbench to stabilize. FlowCom will automatically adjust the motor speed to maintain the test pressure.
14. Verify the test pressure on the FlowCom reads **10.0"**.
15. The FlowCom should now read the flow through the test plate in cfm. Make note of this reading. Press the **LEFT ARROW** key to hold the reading. Record the data, then press the **RIGHT ARROW** key to resume active readings.
16. Turn off the flowbench motor switch and close the intake flow control valve.
17. Compare the measured flow to the expected readings stamped on the test plate or to the nominal values shown in "Table 4-1. Test Plate Nominal Flow Readings*" on page 13. If the measured flow is within 3% of the expected reading, the flowbench and FlowCom are working properly.
18. Switch the flowbench and FlowCom to **exhaust mode** and repeat the above steps (13-17) with the exhaust flow control fully open (CCW).
19. Turn off the flowbench motor switch and close the exhaust flow control valve (CW).
20. Make a note on the test plate of the actual flow reading. This is used for future reference. Remove the test plate and store it in a safe place for future use.

This completes the operational checkout test. If the flowbench meets the expected results within ±3%, the flowbench and FlowCom are working properly. Remove the test orifice plate and proceed with your testing.

IMPORTANT

Use the orifice test plate when test results are questionable. If the test orifice plate flows the same value at it did on the initial checkout, then the flowbench is functioning properly.

4.0 Installation

4.3 Computer Connections

The SuperFlow flowbench can be used as a stand-alone unit with the test pressure and flow measurements displayed on the front panel. However, application software can optimize the system's capabilities. The FlowCom can automatically send all data through its serial port to a computer (PC) with flowbench software. The computer can be connected with either an RS232 serial cable or a Universal Serial Bus (USB) cable to communicate with WinDyn, Port Flow Analyzer, or other flowbench software.

NOTE: USB is only applicable with the new style FlowCom.

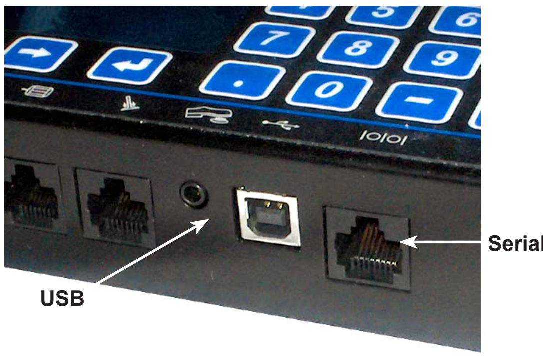
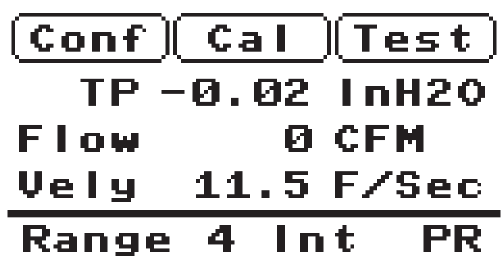


Figure 4.7: Computer Connections

Your computer determines which type of cable will work best. Either cable requires configuring the computer for it. The RS232 cable is the easiest to configure. However, many new computers no longer have this connection as a standard option, so the USB may be the only option and works well once the computer is configured for it.

4.3.1 Configuring FlowCom to Communicate



1. On the **FlowCom panel**, press the red button ( ) to turn the power on. Wait for the current data screen to appear.

2. Press **CONF** (F1) button to access the **Configuration** menu.
3. Press the **DOWN ARROW** button ( ) to scroll to **USB/Serial**.
4. Press the **ENTER** button ( ).
5. Type **3512** for the password. Press **ENTER.**

6. The **Select host connection** screen appears. The current mode is indicated by a box around the connection type - **USB** or **Serial**.
7. Press the **LEFT** or **RIGHT ARROW** buttons (← →) to select the connection type.
8. Press **ENTER.**
9. Press **F1** to exit and return to the main operating screen.

4.3.2 RS232 Serial Connection

An RS232 serial cable can be used with a direct serial port on the computer. In this procedure, a DB9 nine-pin connector is used on the computer configured as a serial port.

You will need a standard Cat-5 cable and an RJ45/DB9 adapter. The Cat-5 cable plugs into the FlowCom serial port. The adapter is used to connect the Cat-5 cable to the nine-pin serial port connection on the computer.

An RJ45/DB9 adapter is not supplied with FlowCom but is available from SuperFlow Customer Service. To order one, call and ask for part number 1200A-1012. Adapters can also be purchased at some computer parts supply stores. A drawing showing the pin connections can be obtained from Customer Service.

1. Ensure that the FlowCom is configured for **Serial** communication.

See section "4.3.1 Configuring FlowCom to Communicate" on page 16.

2. Using the Cat-5 cable and adapter, connect the cable to the nine-pin serial port connection on the computer and to the serial port on FlowCom. Use an extension if necessary.

NOTE: Consult a computer expert if your computer does not have a nine-pin serial connection and you want one installed.

3. Set the software for the proper COM settings according to the instructions that came with the software package.

For SuperFlow WinDyn and Performance Trends Port Flow Analyzer, see section "4.4.3 Checking the COM Port Assignment" on page 21.

4. FlowCom is now ready for operation.

4.3.3 Universal Serial Bus (USB) Connection

The USB communication requires special USB/serial driver software installed on the computer and configured for the correct COM port to communicate with the FlowCom. DO NOT connect a USB cable between the FlowCom and the computer until this driver is installed.

CAUTION

Only computer experts should attempt this configuration. SuperFlow does not guarantee that this is easy or that it works for all computers.

1. Ensure that the FlowCom is configured for **USB** communication.

See section "4.3.1 Configuring FlowCom to Communicate" on page 16.

2. DO NOT connect the cable to the computer at this time.

CAUTION

The USB driver must be installed on the computer before connecting the FlowCom. If the FlowCom is connected and turned on without the driver installed, Windows will detect the new hardware and unsuccessfully attempt to install a driver. To rectify this situation, the driver installed by Windows must be uninstalled and the correct driver installed according to the following procedure.

Installing the USB Driver

The driver software is provided with the flowbench. The software is on the USB thumb-drive that accompanied the equipment. Contact SuperFlow Customer Service if you cannot locate the USB thumb-drive.

1. Insert the USB thumb-drive into one of the computers USB ports.

NOTE: If the program does not automatically start, click **Start** and select **Run**. Type **X:\Setup.exe** (where **X** is the drive letter for your USB drive). Or select **Start>>Run** and then browse for the **Setup.exe** file. Double-click it to start the program.

2. When the **VCP InstallShield Wizard** appears, follow the subsequent instructions.
3. When the **License Agreement** appears, select **I accept the terms of the license agreement**.
4. Click **Next**. If the system checks for compatibility and a **Software Installation** dialog box appears stating the software did not pass the test. This only means the software was not submitted to Microsoft for their approval. The software will not cause any problems with your computer.
5. Click **Continue Anyway**. You may need to do this twice.
6. The **InstallShield Wizard Complete** window appears stating the installation was successful.
7. Click **Finish** to close the program.

4.0 Installation

Configuring the USB Communication

1. Connect the USB cable to the FlowCom and to an available port on the computer. Use an extension if necessary.
2. Power on the FlowCom. When Windows detects the hardware, the **Found New Hardware Wizard** appears.
3. DO NOT allow the wizard to connect to the Internet. Select **No, not this time** and click **Next**.
4. The **Found New Hardware Wizard** software installation window appears.
5. The wizard requests an installation CD, but this is not necessary to complete the installation. Select **Install the software automatically (Recommended)**. Click **Next**.
6. If Windows performs a logo test to check compatibility and a **Hardware Installation** dialog box appears stating the software did not pass the test, this only means the software was not submitted to Microsoft for their approval. The software will not cause any problems with your computer.
7. Click **Continue Anyway**.
8. The **Completing the Found New Hardware Wizard** window appears.
9. The installation for the first device is complete. Click **Finish**.
10. The **Found New Hardware Wizard** will open again to install a second device. Repeat steps 5 through 10.

4.4 Software Programs

4.4.1 Installation and Operation

Refer to the installation and operation instructions that accompanied the software package.

4.4.2 Communications

The software communication must be configured for the correct COM port that FlowCom is using.

- For standard serial communication, this is COM1 or COM2; the serial port on most computers is COM1.
- For USB communication, the USB/serial driver must be assigned to a COM port that the software recognizes.

For WinDyn this must be either COM1 or COM2. Port Flow Analyzer uses ports 1–8.

WinDyn

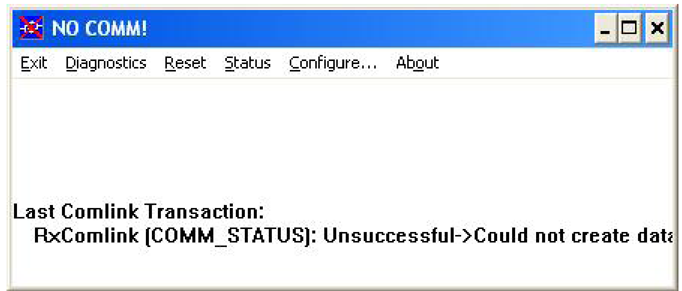
Start WinDyn. The FlowLink program on the taskbar will indicate whether FlowCom is communicating with WinDyn. If a message on the FlowLink bar reads **Comm OK**, nothing else must be done.

4.0 Installation

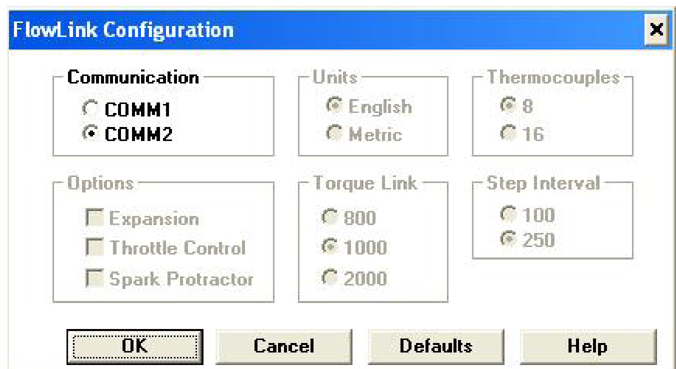
FlowLink Not Communicating

If the FlowCom is flashing **NO COMM!**, you must set the COM ports.

1. Click the **FlowLink** program to open the communications window.



2. From the FlowLink menu, select **Configure....** The **FlowLink Configuration** dialog box appears.
3. Click the desired communication port (**COMM1** or **COMM2**). If you are not certain about which setting to use, refer to section 4.4.3, “Checking the COM Port Assignment,” on page 26 to determine which COM port the FlowCom is connected to.
4. Click OK.
5. Minimize (**do not close**) the FlowLink window; or close and restart WinDyn.



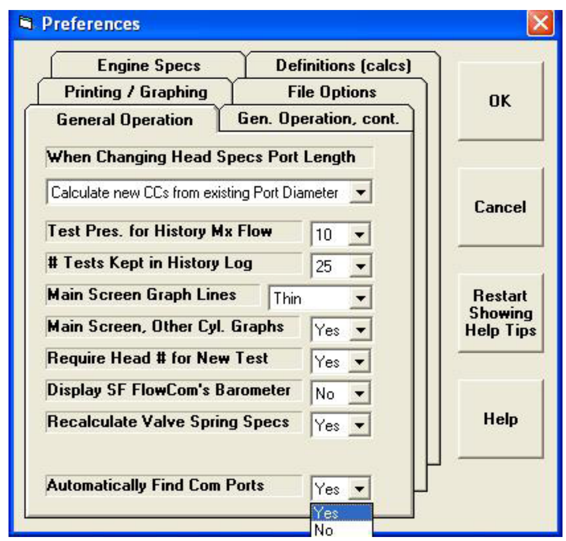
Port Flow Analyzer

Port Flow Analyzer (PFA) version 3.0 or higher can use any COM port between 1 and 8. It can automatically detect the FlowCom and set the COM port accordingly. This is the default preference setting after installation.

1. To check or change the preference setting, click **Preferences** at the top of the main screen, then click the **General Operation** tab.

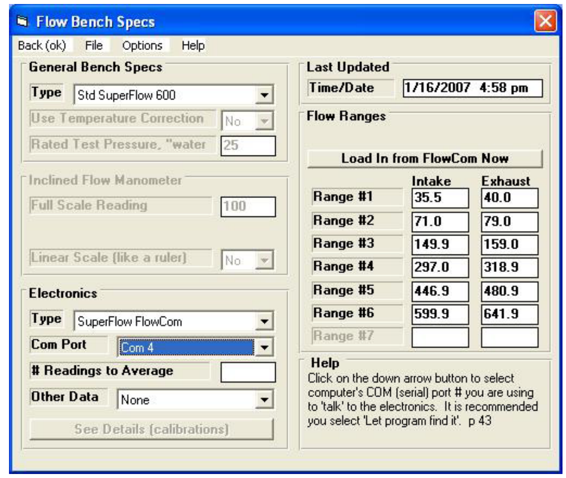
   If the **Automatically Find Com Ports** drop-down list is set to **Yes**, the COM port is automatically detected and set. If set to **No**, the port setting can be manually set.

2. Click **OK** at the top right to keep this setting.



4.0 Installation

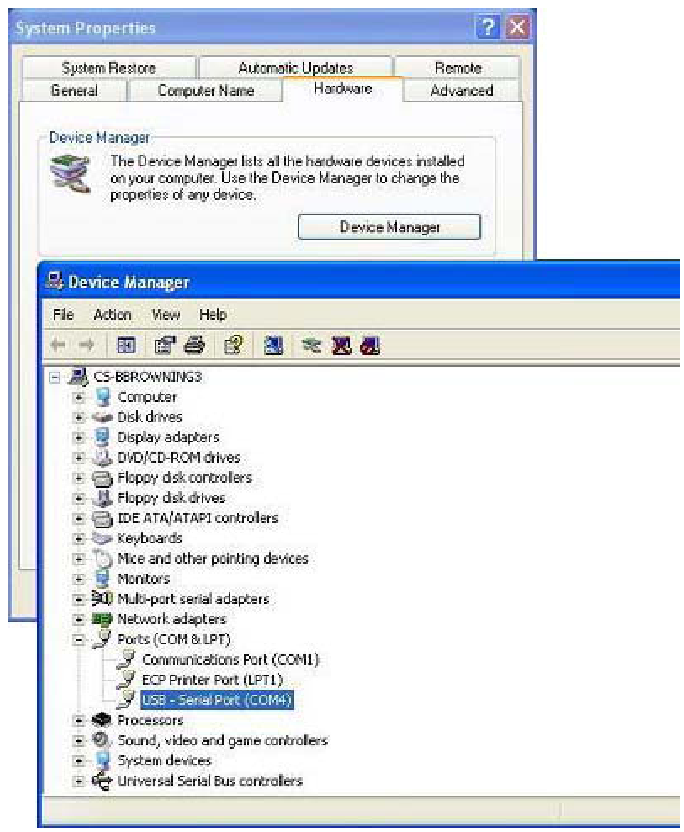
3. Now click **Flow Bench** at the top of the main window. The Flow Bench Specs dialog box appears.
4. In the **Electronics** area (lower left corner), click the **Com Port** drop-down list to select the Com Port to use. If the FlowCom is communicating with PFA, the **Load In from FlowCom Now** button in the right pane is active.
5. When PFA and FlowCom are communicating, the two can be used together.



Refer to the PFA operations manual for further instructions.

4.4.3 Checking the COM Port Assignment

Windows will assign an available COM port to the USB/serial driver. If the flow software is not configured for that COM port, FlowCom cannot communicate properly with the computer. The assigned COM can be verified and changed using the following procedure.



1. Ensure the FlowCom is connected to the computer and is set for USB connection (see section "4.3.1 Configuring FlowCom to Communicate" on page 16).
2. Press the red button ( ) to turn ON the FlowCom power.
3. Open the **Windows Device Manager** and determine which serial port the USB is using:
   - Access the **System Properties** dialog box on the computer.

   Windows software provides several methods for opening the System Properties depending upon how the computer's Start menu and desktop are configured. Refer to the Windows online Help for assistance if you do not know how to open this dialog box, or ask for assistance from someone who knows how to do this.

   - In the **System Properties** dialog box, click the **Hardware** tab.
   - Click the **Device Manager** button to open the dialog box, then click the **PLUS SIGN** (**+**) sign next to **Ports** (**COM & LPT**).

4.0 Installation

- Note which COM port the FlowCom is connected to.
  - The USB/serial port when a USB cable is used.
  - The Communications port when a serial cable is used.
- If the COM port is compatible with the software, close the dialog boxes and use the software communication tools to set the COM port.

Changing the COM Port Assignment

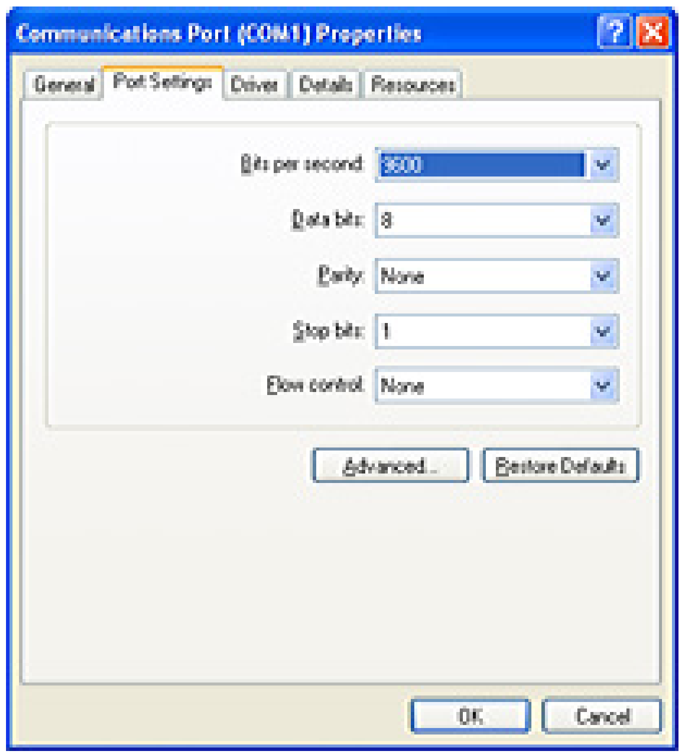
1. On the **Device Manage**r dialog box, select **USB – Serial Port** and double-click or press **ENTER**. The **Communications Port [Port Name] Properties** dialog box appears.
2. Click the **Port Settings** tab, then click the **Advanced** button.
3. The **Advanced Settings for [Port Name]** dialog box appears.
4. The **COM Port Number** displays in the drop-down list at the bottom left. Click the arrow to change the COM port.
5. Click **OK** or close all dialog boxes. Check the flow software for communication.

CAUTION

If no compatible COM ports are available, one must be made available. This may require changes to the Basic Input/Output System (BIOS) settings on the computer which should only be attempted by a computer expert. An option would be to add a serial Input/Output (I/O) device to the computer and use the serial connection setting on the FlowCom.

CAUTION

SuperFlow is not responsible for any damage that may occur to your computer settings if this procedure is not followed correctly.



5.0 Operation

⚠ DANGER

DO NOT remove any safety guards while the machine is in operation, and be sure the safety guards are correctly mounted before operating the device.

⚠ WARNING

WEAR EYE and HEARING PROTECTION. Proper eye and hearing protection should be worn at all times when the equipment is operating.

⚠ WARNING

- **Inspect the equipment monthly to ensure that there are no broken or worn parts which could cause injury to personnel or damage to the equipment.**
- **Only qualified operators and maintenance personnel should perform the procedures covered in this manual.**

⚠ CAUTION

- **Keep the air ducts free of dust or dirt.**
- **Keep loose material away from the inlet and exhaust ducts.**

5.1 The Flow Computer

FlowCom™ is used in conjunction with the SuperFlow flowbench to provide precise flow data in volumetric terms and is easy to use for normal flow testing. After mounting your test piece on the test orifice plate:

- Set the desired test pressure and range.
- Turn the motors on.
- Read the flow directly on the front panel display.

The operator's primary concern is to remember that the range and direction must be set on both the flowbench and on FlowCom so they match. Failure to match the FlowCom and flowbench can result in erroneous data.

FlowCom test data can be manually recorded or automatically recorded by software installed on a connected computer.

If the operator requests a test pressure but the flowbench cannot quite reach that pressure, FlowCom has a unique feature that will display the flow rate at the desired test pressure. This is automatic as long the acquired test pressure is within 50% of the target test pressure. This convenient feature speeds up the testing process considerably. If the acquired test pressure is greater than 50% of the desired pressure, FlowCom will not display a flow reading.

Example:

The target test pressure is set to 1**0 inH$_2$O** but the acquired test pressure is only **8 inH$_2$O**. FlowCom will display a flow rate as it would be if the test pressure were at 10 inches.

The advanced features of FlowCom allow you to select the units of measurements and add options such as velocity probes.

5.0 Operation

5.1.1 Display Panel and Keypad

The front panel provides the FlowCom operator controls. The push-button controls are encased in the membrane panel for greater reliability. Data is viewed on a 128x64 Liquid Crystal Display (LCD). Light-Emitting Diode (LED) lights indicate power, motors, and direction status.

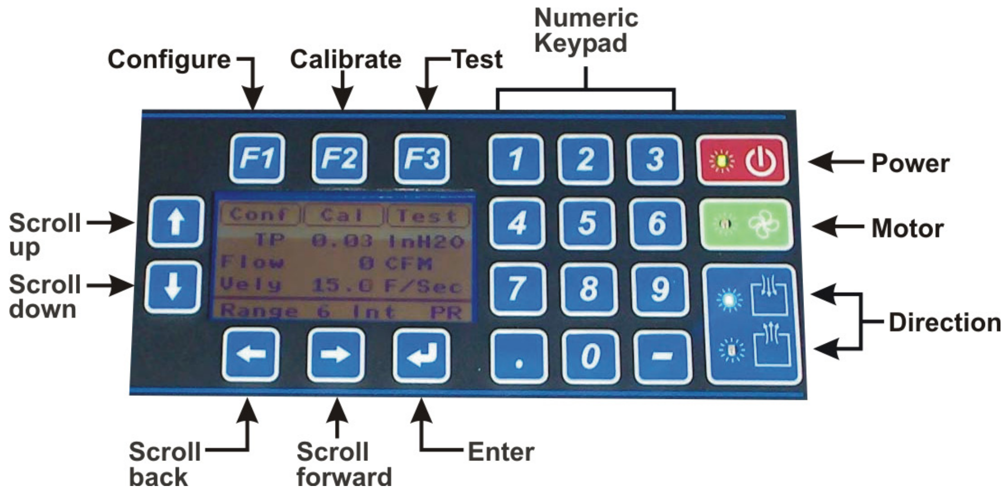


Figure 5.1: FlowCom Operator Panel

Table 5-1. Keypad Functions

Graphic	Key Name	Function	Description
	RED	Power	Turns the power on and off.
	GREEN	Motor	Turns the flowbench motors on and off.
	BLUE	Direction	Selects intake or exhaust mode. The upper button (blue LED) indicates intake; the lower button (amber LED) is exhaust.
	UP ARROW	Scroll Up	Selects items on the display.
	DOWN ARROW	Scroll Down	Selects items on the display.
	F1	Configuration	Accesses a menu for FlowCom general setup and configuration.
	F2	Calibration	Accesses the calibration functions.
	F3	Test	Accesses the test functions.
	BACK ARROW	Scroll Back	Selects items on the display.
	FORWARD ARROW	Scroll Forward	Selects items on the display.
	BENT ARROW	Enter	Activates the current selection.

5.1.2 FlowCom Connections

FlowCom connections are located on the side panel with a graphic representation on the front panel.

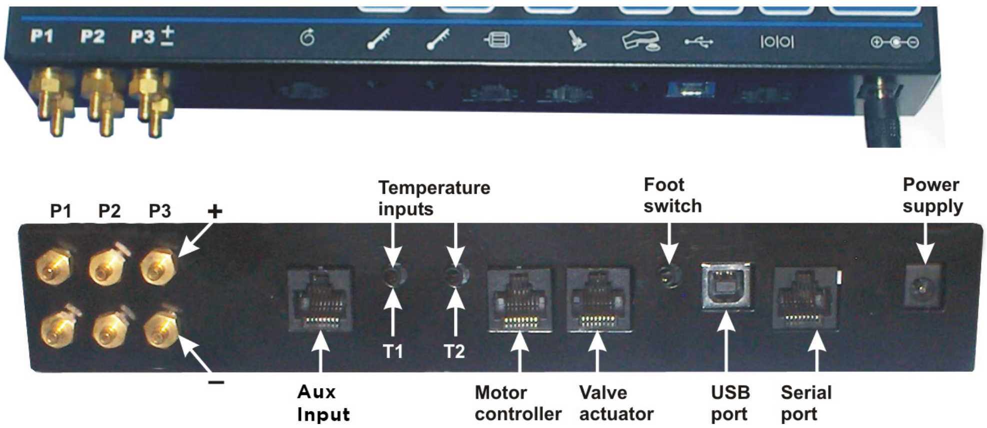


Figure 5.2: FlowCom Connections

- **P1 Flow Pressure:** Measures the pressure difference above and below the five sharp-edged orifices on the plate at the top of the flowbench as the air flows through them.
- **P2 Test Pressure:** Measures the pressure or vacuum at the base of the flowbench where the test piece is mounted as referenced to the relative pressure outside the flowbench.

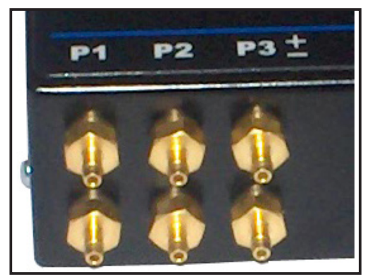


Figure 5.3:
FlowCom Pressure Ports

Refer to section "3.3 FlowCom" on page 8 for information on connecting the FlowCom ports to the flowbench.

- **P3 Velocity Probes:** This connection provides for readings of velocity when Pitot tubes are attached. The bottom of the pitot tube (impact connection) connects to the port marked **P3+**. The static port (90° side connection) connects to the port marked **P3–**. These connections allow the FlowCom to provide direct velocity readings or % of velocity. No additional calculations are necessary when using the SuperFlow FlowCom device with the correct pitot tube because the velocity value automatically displays in almost real-time.

For more information on Pitot tubes, refer to Appendix G, “Pitot Tubes and Applications.”

- **Aux Input:** This RJ-45 connection provides an input of a voltage or frequency signal from a swirl meter, strain gauge, or other analog device. The connector wiring is shown in Figure 5-4. The signal displays as raw data on the FlowCom and as calculated swirl on a connected computer with suitable flowbench software. WinDyn can convert the raw data to any format based on the signal type.

Aux Input		
	1	+5V
	2	Aux Sig+
	3	Analog gnd
	4	Aux Sig-
	5	Chassis gnd
	6	+3V
	7	Freq MAG
	8	Freq TTL
	9	Analog gnd

Figure 5.4: Aux Input Connector Wiring

5.0 Operation

- **Temperature Inputs:** 1/8-inch phone plug connection for temperature sensors. One of these sensors is generally used to measure the air temperature in the chamber under the flowbench baseplate.

  When used with a motor controller, the FlowCom is programmed to display a warning if the temperature on either sensor reaches 190°F and shuts the motors off if the temperature exceeds 216°F.
- **Motor Controller:** When equipped with a motor controller, FlowCom automatically controls the speed of the motors to maintain the desired test pressure or flow. This RJ-45 (Cat-5) connection requires an RJ-45 to 9-pin DSUB adapter on the motor controller (SuperFlow part number 1200A-1011).
- **Valve Actuator:** This RJ-45 connection is designated for a special valve lifter module.

NOTE: The module is not available at the time of this writing.

- **Foot Switch:** Provides a hands-free method for the operator to freeze the FlowCom reading on the display so data can be recorded. When used with WinDyn™ or Port Flow Analyzer™, it also records data in the software.

  The foot switch requires a single-pole, normally open, momentary contact push-button switch with a standard 1/8-inch male phone plug (not included with the flowbench).
- **USB Port:** Universal Serial Bus communications port for connecting a computer.

See "4.3 Computer Connections" on page 16 for more information.

- **Serial Port:** RS-232 serial communications port. (Computer will require an RJ-45 to DSUB adapter).

See "4.3 Computer Connections" on page 16 for more information.

- **Power:** This connection is for a 9VDC, 300mA power supply when the FlowCom is not used with a motor controller (SuperFlow part number E4190P- 3590).

5.1.3 FlowCom Channels

The values displayed on the front panel are referred to as channels. Fourteen channels are available; select any of these to display on the FlowCom.

For the procedure for changing the displays, see section "5.2.3 Setting the Units of Measurement" on page 31.

Table 5-2. FlowCom Channels

Channel Number	Channel Name	Channel Type	Channel Description	Units Of Measurements
1	**Flow Press**	Measured	Pressure difference across the flow orifice	InH_2O, cmH_20, mm/Hg, or mBar
2	**Test Press**	Measured	Pressure at the base of the test orifice as referenced to atmosphere	InH_2O, cmH_20, mm/Hg, or mBar
3	**Velocity Press**	Measured	Pressure difference across the two ports of a velocity probe (or Pitot tube)	InH_2O, cmH_20, mm/Hg, or mBar
4	**Baro Press**	Measured	Atmospheric pressure (uncorrected for sea level)	In/Hg, psi, or kPa
5	**Temp #2**	Measured	Motor chamber air temperature	Fahrenheit, Celsius, or Kelvin
6	**Temp #1**	Measured	Air temperature in the chamber under the baseplate	Fahrenheit, Celsius, or Kelvin
7	**Aux Input**	Measured	Measured voltage input from a strain gauge, load cell, or swirl meter; available on the front panel	N-m, lb-ft, or swirl
8	**Temp #3**	Measured	Range orifice position	Range number
9	**Flow Rate**	Calculated	Airflow rate based on flow pressure measurement	cfm, lps, or cmh
10	**Velocity**	Calculated	Air speed in distance or percent based on Velocity pressure input	%Velc, F/Sec, or m/Sec
11	**Delta-T**	Calculated	Temperature difference between Temp #1 and Temp #2 (T1–T2)	Fahrenheit, Celsius, or Kelvin
12	**% of Flow**	Calculated	Percentage of the full-scale capacity of the range in use	% F.S.
13	**Rel Swirl**	Calculated	Measured swirl value (frequency or voltage) divided by the flow rate	Swirl
14	**Frequency**	Calculated	Frequency input from a swirl meter or other device	Hertz, swirl, or rpm

5.0 Operation

5.2 FlowCom Operation

IMPORTANT

The easiest way to learn and master the basic operation of the flowbench is to flow the test orifice plate according to section "4.2 Operational Check" on page 13.

When you first turn on the FlowCom power, a window appears displaying **SuperFlow Technologies Group, FlowCom**, the **firmware version number**, and the flowbench model. This display is quickly followed by the current data screen showing normal test readouts ("Figure 5.5: Current Data Screen").

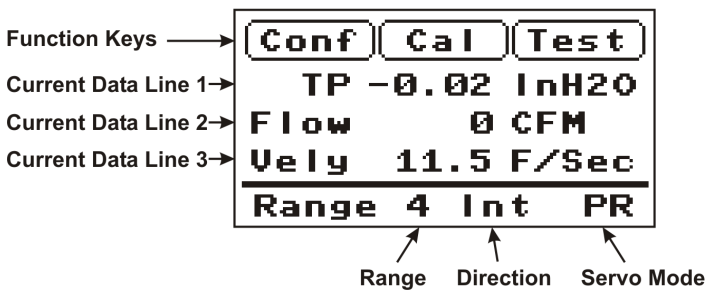


Figure 5.5: Current Data Screen

The top line shows an abbreviated description of the function keys above the display ("Table 5-1. Keypad Functions" on page 24).

The three middle lines display the test values. For the purpose of detailing the basic operation, the default channels are shown: Test Pressure, Flow Rate, and Velocity. Most testing requires only this screen. As shown in "Figure 5.5: Current Data Screen", the top current data line reads test pressure in inches of water (inH_2O). The middle reading is the test flow in cfm. The bottom reading is the % of maximum velocity when the velocity probe is used.

The displayed channel selection can be changed if desired. See section "5.2.3 Setting the Units of Measurement" on page 31.

The bottom line shows the current range, flow direction, and servo mode:

- **Range:** The number indicates the range (1–9)
- **Direction:**
  - **Int:** Intake
  - **Exh:** Exhaust
- **Servo Mode:**
  - **PR:** Test Pressure
  - **FL:** Flow Rate

This flowbench display shown in Figure 5.2 is in Range **4**, **Intake** mode, and controlling **Test Pressure**.

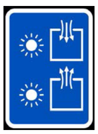
5.2.1 Setting the Flow Direction and Range

IMPORTANT
To obtain the correct readings, the flow direction and range settings on the FlowCom must match the mechanical settings on the flowbench, even if using a motor controller.

You can set the flow direction and flow range in several ways. The quickest method is to use the direction button and numeric keypad on the FlowCom panel (see "Figure 5.1: FlowCom Operator Panel"). If desired, the direction and range can be selected individually through display menus. One final method allows you to set both the direction and range on one display menu.

Flow Direction

Method 1

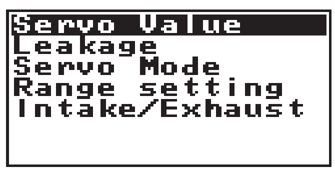


Press the **Direction** button on the FlowCom panel. The upper button is for **Intake** mode (blue light) and the lower button is for **Exhaust** mode (amber light).

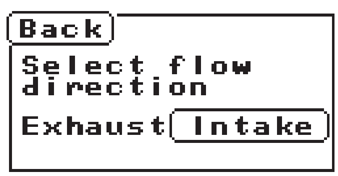
The selected flow direction displays on the bottom line.

Method 2

1. Press **TEST** button (F3) on the FlowCom panel. The **Test** menu appears.



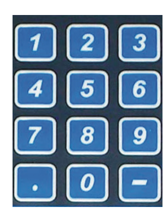
2. Use the **DOWN ARROW** button to scroll to **Intake/Exhaust**. Press **ENTER** button ( ). The **Select Flow Direction** screen appears.



3. Press the **LEFT** or **RIGHT ARROW** button to select the desired direction. Press **ENTER**. The display returns to the previous screen. Press **F3** button to exit and return to the current data screen which indicates the selected direction on the bottom display line.

Flow Range

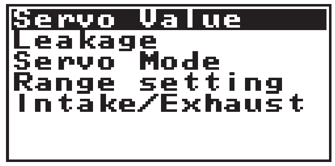
Press the range number on the numeric keypad. The selected range displays on the bottom line of the display.



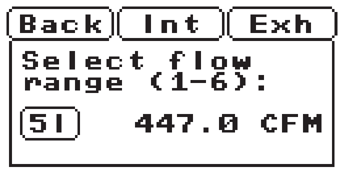
5.0 Operation

Flow Direction and Range

1. Press **TEST** button (F3) on the FlowCom panel. The **Test** menu appears.



2. Use the **DOWN ARROW** button to scroll to **Range Setting**. Press **ENTER** button (↵). The **Select flow range** screen appears.



3. Press the **F2 (Intake)** or **F3 (Exhaust)** buttons to select the flow direction. Press the **UP** or **DOWN ARROW** buttons to scroll to the desired range. The full-scale flow reading for that range and direction displays on the screen.
4. Press **F1 (Back)** to return to the previous screen. Press any of the **F** buttons to return to the current data screen.

5.2.2 Setting the Test Pressure

The **Test Pressure** setting is important for FlowCom to calculate the correct flow rate. When a motor controller is used, FlowCom automatically adjusts the motor speed to maintain the desired test pressure. To set the **Test Pressure**, enter the desired value on the FlowCom panel. You can access thetest pressure menu in one of two ways:

Method 1

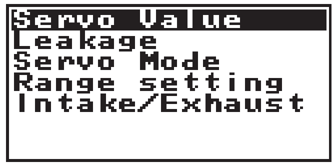
1. While viewing the current data screen, press the **ENTER** button (↵) under the **PR** label. The **Enter new test pressure** screen appears.

   The display will show the current test pressure setting and the units of measurement. You can use the **LEFT** and **RIGHT ARROW** buttons to switch between the two values.
2. With the pressure value selected (as shown), enter a value using the numeric keypad.
3. Press **ENTER**. The units of measurement will highlight.
4. Use the **UP** or **DOWN ARROW** buttons to select the units (inH_2O, cmH_2O, mmHg, or mBar).
5. Press **ENTER** to exit and return to the current data screen.

5.0 Operation

Method 2

1. Press **TEST** button (F3) on the FlowCom panel. The **Test** menu appears.



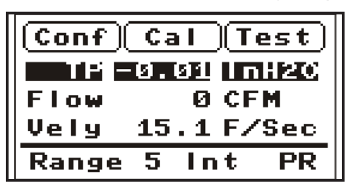
2. **Servo Value** should be selected. If not, use the **UP** or **DOWN ARROW** buttons to scroll to it.
3. Press **ENTER** button (↵). The **Enter new test pressure** screen appears.

4. With the pressure value selected (as shown), enter a value using the numeric keypad.
5. Press **ENTER**. The units of measurement then highlight.
6. Use the **UP** or **DOWN ARROW** buttons to select the units (inH_2O, cmH_2O, mmHg, or mBar).
7. Press **ENTER** to exit and return to the **current data screen**.

5.2.3 Setting the Units of Measurement

The current data screen can show any three of the channels defined in the FlowCom (see "Table 5-2. FlowCom Channels" on page 27) with several different units of measurements available.

1. To set the displayed channel and units of measurement from the **current data screen**, press the **DOWN ARROW** button until the desired line on the display highlights.



2. Press **ENTER** button (↵). The **Select channel to display** screen appears.

3. Use the **UP** or **DOWN ARROW** buttons to scroll to the desired channel.
4. Press **ENTER** to access the **Enter units of [Flow Rate]** screen.

5. Use the **UP** or **DOWN ARROW** buttons to scroll to the units of measurement.
6. Press **ENTER** to exit and return to the current data screen.

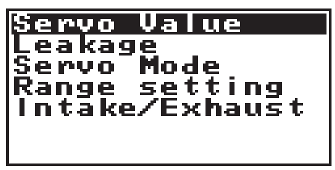
5.2.4 Selecting Displayed Channels

See section "5.2.3 Setting the Units of Measurement" on page 31.

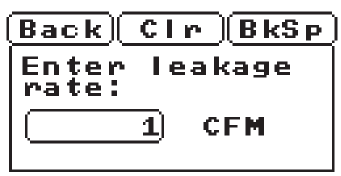
5.2.5 Leakage

The flowbench measures all airflow between the calibrated range orifice and the open end of the device under test, including air leakage anywhere in the path. This leakage can be measured and compensated for in the FlowCom flow readings.

1. Press **TEST** button (F3) on the FlowCom panel. The **Test** menu appears.



2. Use the **UP** or **DOWN ARROW** buttons to scroll to **Leakage**. Press **ENTER** button (). The **Enter leakage rate** screen appears.



3. Using the numeric keypad, press **0**, then press **ENTER**.
4. Use the **UP** or **DOWN ARROW** buttons to scroll to the desired units of measurement. This must match the units used in the normal testing.
5. Press **ENTER** to return to the previous screen.
6. Press any of the **F** keys to return to the current data screen.

IMPORTANT
Keep in mind that the leakage value entered in the FlowCom remains until the next time it is changed.

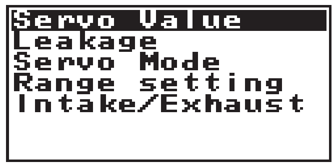
See section "5.7.2 Correcting for Leakage" on page 42 for more information on leakage.

5.0 Operation

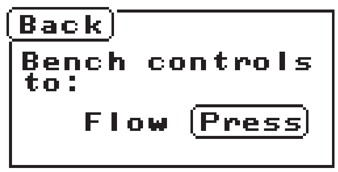
5.2.6 Setting the Servo Mode

The SF-750 is capable of controlling the airflow to either **test pressure** or **flow rate**. In test pressure servo mode, the air pressure is set and the flow rate measured. In flow rate servo mode, the airflow is set and the test pressure measured.

1. To change the servo mode in the Test menu, **TEST** button (F3) on the FlowCom panel. The **Test** menu appears.



1. Use the **DOWN ARROW** button to scroll to **Servo Mode**.
2. Press **ENTER** button (). The **Bench controls to:** screen appears (servo mode).



3. Use the **LEFT** or **RIGHT ARROW** buttons to select a setting.
4. Press **ENTER** to set the servo mode and return to the previous screen.
5. Press any of the **F** keys to return to the **current data screen**.

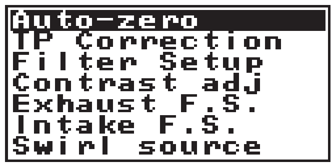
From this point on (or until the servo mode is changed), FlowCom will control the airflow to the selected servo mode. The label above the ENTER button indicates what mode the FlowCom is in (PR = Test Pressure, FL = Flow Rate).

5.0 Operation

5.3 FlowCom Configuration

The Configuration menu in FlowCom allows the operator to access special features. Some of these features are used in normal operation, some are for special applications, and some are critical for proper flowbench operation. The critical features are password protected to prevent inadvertent access.

1. Press the **CONF** (F1) button to access the **Configuration** menu.
2. Use the **UP** or **DOWN ARROW** buttons to scroll to the desired feature.
3. Press the **ENTER** button () to access the feature.
4. Press any of the **F** buttons to return to the Configuration menu current data screen.

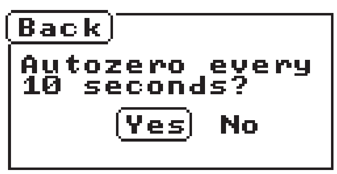


5.3.1 Autozero

This function sets all of the measured sensor channels except temperature and barometric pressure to zero. Do not make this selection if any pressure, frequency, or torque is applied to the sensors.

On the SF-1020, the pressure transducers are automatically autozeroed every 10 seconds when the motor is OFF as long as **Autozero all channels now** is set to **YES**. This feature can be turned off if desired.

IMPORTANT
With the automatic autozero turned off, the sensor will never be zeroed unless the feature is turned back on. Only use this option in situations of rapid motor cycling where the pressures may not have time to settle back to zero between tests.



1. Use the **LEFT** or **RIGHT ARROW** buttons to select **Yes**.
2. Press **ENTER** button () to perform the action and return to the previous screen.

5.3.2 TP Correction

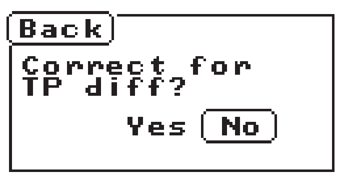
The FlowCom is calibrated at the factory using a standard 25 inH_2O of test pressure in all ranges. If the test pressure used is considerably different, the flow rate reading may be slightly inaccurate (approximately 1%). This can significantly affect readings, especially when controlling to flow rate.

Table 5-3. Test Pressure Correction Factors

Test Pressure	Intake Flow	Exhaust Flow
48" (120 cm)	0.978	1.019
36" (91.4 cm)	0.989	1.009
28" (71.1 cm)	0.997	1.003
25" (63.5 cm)	1.000	1.000
20" (50.8 cm)	1.005	0.996
15" (38.1 cm)	1.010	0.992
10" (25.4 cm)	1.014	0.988
5" (12.7 cm)	1.019	0.984

To compensate for this factor, a feature is built into the FlowCom to adjust the measurements accordingly. The **Test Pressure Correction** corrects the flow measurement when measured test pressure varies significantly away from where the flowbench is designed to operate at. On FlowCom equipped with a motor controller, this correction operates in both test pressure and flow control modes.

This feature can be enabled or disabled as desired. By default this feature is turned off, follow the steps below to turn on.



1. Use the **LEFT** or **RIGHT ARROW** buttons to select a setting.
2. Press **ENTER** button () to perform the action and return to the previous screen.
3. Press the **BACK** button to cancel the operation and exit the screen.

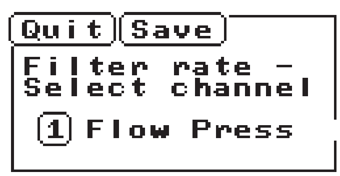
5.3.3 Filter Setup

The **Filter Setup** selects the filtration rates for averaging the displayed data of measured channels. TFilter rates can be selected individually on each sensor input. No change is usually required for these values.

Table 5-4. FlowCom Filters

Filter Number	Time (seconds)
0	No Filter
1	0.15
2	0.34
3	0.72
4	1.49
5	3.02
6	6.10
7	12.24
8	24.48

1. Press the **F1 (Conf)** button to access the **Configuration** menu.
2. Use the **UP** or **DOWN ARROW** buttons to scroll to Filter Setup.
3. Press the **ENTER** button ( ) to access the feature.



4. Use the **UP** or **DOWN ARROW** buttons to scroll to the desired channel, or press **Quit** to return to the previous screen without affecting the current settings. Press **Save** to accept changes and return to the previous screen.
5. Press **ENTER** to access the **Select filter rate** screen.

6. Enter the desired filter rate for the selected channel.

7. Press **ENTER** to accept the change and return to the previous screen.
    - The **CLR** button clears the entered value.
    - The **BKSP** button moves the cursor back one position.
    - **QUIT** cancels the operation and returns to the previous screen.
8. Press **Save** to accept the current settings and return to the current data screen.
9. Press any of the **F** buttons to return to the current data screen.

5.3.4 Adjusting Contrast

You can adjust the contrast on the FlowCom LCD display for better viewing.

1. Press and release the **LEFT** or **RIGHT ARROW** buttons to adjust the display contrast. One press moves the bar one position.
2. Press **DEFT** to return the contrast to the default factory setting.
3. Press **SAVE** to accept the new setting and return to the previous screen.

5.3.5 Exhaust Full Scale (F.S.)

Use **Exhaust Full Scale** to change the full-scale flow value for each of the available exhaust flow ranges. This feature requires a password to access the function. Do not change these values unless you have accurate calibration data. The correct values are listed on the calibration sheet shipped with the flowbench or obtained when the flowbench is calibrated.

See section "6.5.3 FlowCom Range Calibration" on page 58.

5.3.6 Intake Full Scale (F.S.)

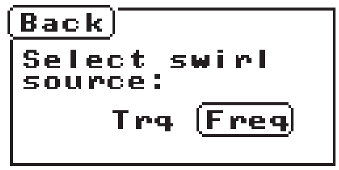
Use **Intake Full Scale** to change the full-scale flow value for each of the available intake flow ranges. This feature requires a password to access the function. Do not change these values unless you have accurate calibration data. The correct values are listed on the calibration sheet shipped with the flowbench or obtained when the flowbench is calibrated.

See section "6.5.3 FlowCom Range Calibration" on page 58.

5.3.7 Swirl Source

Set Swirl Source selects whether a frequency or torque type swirl meter is used. This function has no effect if you do not have a swirl meter.

1. Enter the password **3512** to access the **Select swirl source** screen.



2. Use the **LEFT** or **RIGHT ARROW** button to select the desired setting.
3. Press **ENTER** button ( ) to accept the change and return to the previous screen.
4. Press **BACK** to cancel the operation and exit the screen.

5.3.8 Pulses/Rev

Frq. Pulses/Rev sets the counts per revolution for frequency type swirl meters.

1. Enter the password **3512** to access the **Enter swirl pulses/rev** screen.

2. Use the numeric keypad to enter the correct number of pulses per revolution for the swirl meter according to the manufacturer's specifications.
3. 3. Press **ENTER** button ( ) to accept the entry and return to the previous screen.
4. 4. Press **BACK** to cancel the operation and exit the screen.
5. 5. Press **CLR** to clear the current value.

5.3.9 Serial/USB

FlowCom can automatically send all data through its serial port to a computer with flowbench software. The computer can be connected with either an RS232 serial cable or a Universal Serial Bus (USB) cable to communicate with WinDyn™, Port Flow Analyzer™, or other flowbench software.

See section "4.3 Computer Connections" on page 16 for more information and instructions.

5.3.10 Config P/I

FlowCom utilizes a closed-loop feedback system for controlling the test pressure or flow rate. This system requires values known as P and I terms. These values can be changed if the conditions warrant it. The default values are usually sufficient for most applications and should not require alteration. This feature requires a password to access the function.

To access and change the **PI** settings:

1. Turn on the FlowCom power.
2. Press the **F1 (Conf)** button to access the Configuration menu.
3. Use the **UP** or **DOWN ARROW** buttons to scroll to **Config P/I**. Press **ENTER** button (↵).
4. Type **3512** for the password.
   - Table 5-5 shows the values set into the FlowCom for an SF-260 flowbench. The four settings are two **P** values and two **I** values, one each for pressure and flow.

Table 5-5. Default P/I Values

Control Mode	P	I
Test Pressure	100	100
Flow Rate	100	100

   - Use the **ENTER** button to scroll to each setting.
   - Use the numeric keypad to enter a value.
   - Press **ENTER** to exit to the **Config** menu.
5. Press any of the **F** buttons to return to the current data screen.

5.4 Flow Testing

What is a Flow Test?

In its simplest form, flow testing consists of blowing or sucking air through a test device at a constant pressure and measuring the airflow. After making a change, the device can be re-tested. The difference in airflow indicates whether the change was an improvement or not. If the tests are made under the same basic conditions, no corrections for atmospheric conditions or machine variations are required and the results may be compared directly.

At the other extreme, it is possible to adjust and correct for all variations so test results may be compared to those of any other similar device tested under any conditions or on any other SuperFlow flowbench.

5.5 Flowbench Ranges

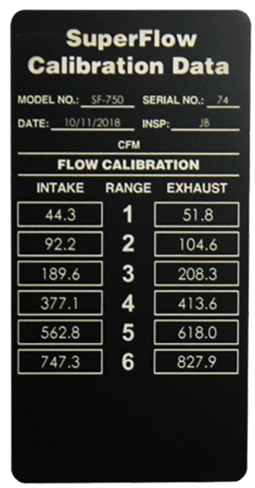
Table 5-6. SF-260 Nominal Flow Ranges

Range Number	Nominal Full-Scale Range Flow @ 10"H_2O*	Upper Orifice Combination
1	15 cfm	1 open (● ● ● ● ○)
2	30 cfm	2 open (● ● ● ○ ●)
3	45 cfm	1 + 2 open (● ● ● ○ ○)
4	60 cfm	1 + 3 open (● ● ○ ● ○)
5	90 cfm	1 + 2 + 3 open (● ● ○ ○ ○)
6	130 cfm	1 + 3 + 4 open (● ○ ○ ● ○)
7	160 cfm	1 + 2 + 3 + 4 open (● ○ ○ ○ ○)
8	215 cfm	1 + 2 + 3 + 5 open (○ ● ○ ○ ○)
9†	280 cfm	All open (○ ○ ○ ○ ○)

* The actual full-scale range is determined by the calibration of the flowbench.

† The maximum flow capacity of the flowbench is proportional to the line voltage. At voltages below the listed rating for the flowbench, the capacity in range 9 will be less than nominal. This does not have any effect on the accuracy.

The SF-260 has 9 flow ranges (see "Table 5-6. SF-260 Nominal Flow Ranges"). Each flowbench comes with a calibration sheet attached to the front panel. This sheet lists the full-scale range values for each range in both flow directions.



These range values will already be entered into FlowCom memory and FlowCom will calculate the flow rate automatically.

Select the range on the flowbench by inserting rubber stoppers in the proper holes on the upper orifice plate at the top of the flowbench. Select the range on FlowCom by pressing the appropriate number on the keypad.

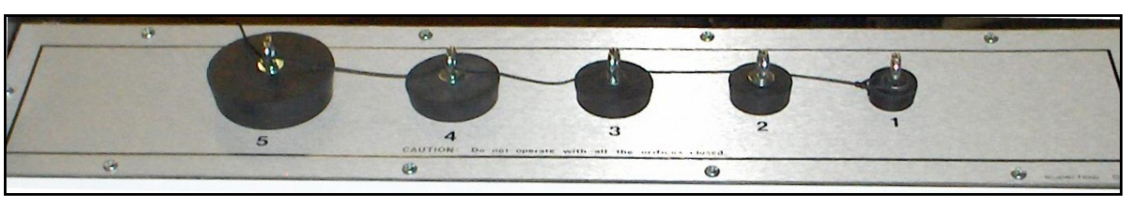


Figure 5.6: Range Orifice Plate

Always turn the motors OFF when switching flow ranges.

The flowbench is designed with multiple ranges to measure the flow accurately. Perform flow testing

IMPORTANT
The range and flow direction settings on the flowbench and on FlowCom must match to obtain the correct results.

in the range that provides a flow rate between 50% and 100% of the full-scale range. If uncertain of the correct range to use, start with a high range and move down until you find the correct range. For greatest accuracy, always test in the lowest range possible. If over 100% of range, then move up one range. If less than 50% of range, then move down one range.

A channel on the FlowCom can be used to view the flow range percentage (channel # 12, % of Flow).

5.6 Flow Direction

The lever control on the panel serves two functions: it sets the direction of airflow through the flowbench by selecting intake or exhaust flow direction and provides an air bypass for cooling the motors at low flow rates. The panel is labeled **Flow Direction**.

The flowbench motors operate most efficiently when more air is passing through them. At lower flow rates, the air inside the motor chamber tends to heat up faster. The bypass air control lets the air circulate more within the flowbench cabinet providing cooling air for the motor/blower section in either intake or exhaust direction.

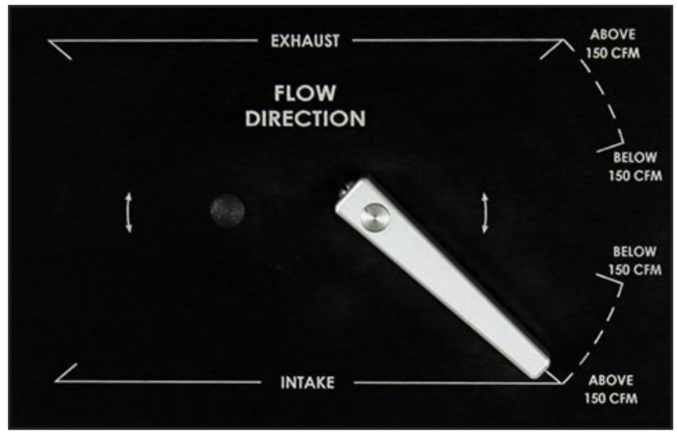


Figure 5.7: Flow Direction and Bypass

The path for cooling air when using the bypass is air entering through the vent on one side of the cabinet, through the motor chamber, and exiting through the vent on the other side of the cabinet. It is this flow path that requires the bench to have clearance on each side. Using the bypass does not affect the accuracy of the flowbench measurements, but it will affect total capacity.

Use the **BELOW 150 CFM** position in the selected flow direction until the flowbench no longer can produce the desired test pressure. Then close the bypass slightly and continue testing until you run out of control valve travel again. To obtain maximum capacity, position the bypass air lever to the **ABOVE 150 CFM** position (no bypass cooling air is available in this position).

It is possible to put the bypass in the middle (horizontal) position for maximum cooling. However, this should only be done for very low flow rates in range 1. In this position the bypass openings are equal on both sides of the motor chamber, so it is feasible that all the air generated by the motors will pass through the cabinet and very little will reach the baseplate.

Perhaps a better way to consider the function of the bypass air positions are **Max** (horizontal), **Some** (either 2 o'clock or 4 o'clock positions), or **None** (either 1 o'clock or 5 o'clock positions).

5.0 Operation

5.7 Performing a Flow Test

NOTE: For reference purposes, the part being tested is called the “test device.” The part of the flowbench where the test device is mounted is called the “baseplate.”

Prior to testing, check the flowbench using the test orifice plate (see section "4.2 Operational Check" on page 13). This procedure is not time consuming and ensures the test results are valid and repeatable.

TIP: The best way to learn how to operate the flowbench is to use the test plate. The small hole in the test plate can be considered “leakage” and the large hole as the “test device.”

5.7.1 Pre-Test Preliminaries

Remove the test orifice plate from the flowbench and install the test device onto the flowbench baseplate with any accessories required (valve opener, radius guide, etc.). Ensure a good seal between the test device and the baseplate.

5.7.2 Correcting for Leakage

Leakage is defined as airflow through any opening other than through the test device. The amount of leakage determined in a test should always be accounted for in the flow data, especially if the leakage varies from test to test. After recording the final flow results, the leakage is subtracted from the raw flow data to obtain the actual flow rate of the test device.

To perform a leak test, you must seal off the normal open port on the test device. On cylinder heads, this means the valves are closed. Other devices may require some sort of cover or block-off plate.

IMPORTANT
If testing in exhaust mode, make sure the cover is secured or it will be blown off.

Leakage can run from 0.5 to 10 cfm (0.25 to 5.0 l/s). If no leakage occurs, the test pressure may rise to the top of the meter. This does not matter as long as the flow meter reads zero. The leakage will not affect the test as long as you correct for it in your results.

On flowbenches with FlowCom, you can enter the leakage into the FlowCom which then automatically subtracts that amount from all subsequent tests. If a leakage test is not performed or no leakage exists, enter a value of zero (**0**) into FlowCom.

Perform the leakage test according to the procedure below. Use the same mode and test pressure that will be used in the normal test.

See section "5.2.5 Leakage" on page 32 for more information on leakage settings in FlowCom.

Performing a Leak Test

NOTE: This procedure assumes testing is conducted in intake mode. Testing in exhaust mode is conducted the same way, except the flow direction is reversed.

1. Close all normal openings on the test device (close the valves on a cylinder head, block off the end of a filter or muffler, etc.).

2. Close (clockwise, CW) the intake and exhaust flow control valves lightly against their seats. DO NOT force them or they will be damaged.
3. Turn the direction selector controls to **Intake**.
4. Insert rubber stoppers in all holes in the upper orifice plate on the top of the flowbench except for hole #1. This is range **#1**.
5. **FlowCom:** Set the following:
   - **Intake, range #1** (see section "5.2.1 Setting the Flow Direction and Range" on page 29).
   - **Leakage** to zero **(0)** (see section "5.2.5 Leakage" on page 32).
   - **Test Pressure** (see section "5.2.2 Setting the Test Pressure" on page 30).
6. **FlowCom with motor controller:**
   - Fully open the intake flow control valve.
7. Turn on the flowbench motor switch.
   - The green push-button switch on the FlowCom panel turns the motors ON. FlowCom automatically adjusts the motor power output for the test pressure.
8. Record the flow from FlowCom.
9. Turn off the flowbench motor and close the flow control valve.
10. Determine and record the flow rate from the flow meter and calibration chart on the front of the flowbench, or use the flow rate value from FlowCom.

Example: Assume the test pressure is 10". In range #1 with a nominal full-scale range value of 10 cfm, 45% percent of flow reading would indicate a leakage flow of **0.45 x 10 cfm = 4.5 cfm**.

- Enter the leakage value (see section "5.2.5 Leakage" on page 32).

IMPORTANT
Keep in mind that the leakage value entered in the FlowCom remains until the next time it is changed.

5.7.3 Performing a Flow Test

The following procedure covers the basic principles of flow testing on a SuperFlow flowbench.

Refer to chapter "8.0 Flowbench Applications and Techniques" on page 77 for more specific information on test applications. For more detailed information on FlowCom, refer to section "5.2 FlowCom Operation" on page 28.

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1. Remove any cover from the test device, or open the cylinder valve to the desired lift point.
2. Turn the **Intake/Exhaust** selector knob to the desired flow direction and place rubber stoppers into the orifices at the top of the flowbench for the desired range. If not certain of the range, select a high range first and move down as necessary.
3. FlowCom only: Set the range corresponding to the stoppers on the upper orifice plate setting the flowbench range and enter the desired test pressure.

4. Set the **flow control** valves. Close them lightly against their seats. Do not force them or they will be damaged.
    - Close (CW) the flow control valve for the direction mode not used. Fully open (CCW) the valve for the direction to be used. FlowCom will control the motor speed to maintain the desired test pressure or flow rate.
5. Turn on the flowbench motors.
    - Turn the flowbench motor switch on, then press the green motor switch on the FlowCom.
6. Set the flow control:
    - FlowCom automatically adjusts the motor speed to stabilize the test pressure at the entered value.
7. Allow the test pressure to stabilize.
8. Observe and record the flow reading from FlowCom. If flow software is installed, press the **Record** button according to the software instructions.
9. Turn off the flowbench motor.
10. This completes the basic flow-testing procedure.

5.7.4 Analyzing the Test Data

For simple analysis of the test results, it is only necessary to observe the **Measured Test Flow** (sometimes referred to as **Flowbench Flow**), or observe **Test Pressure** if FlowCom is controlling to **Flow Rate**. This flow or pressure can be compared to other tests of the same test device with the same setup without further calculations. Because of the flowbench design, air temperature and atmospheric pressure differences cancel out automatically.

NOTE: FlowCom will automatically calculate the measured flow rate by combining the raw flow measured by the flowbench with the leakage value entered into the FlowCom and applying the temperature correction factor as determined by the sensors connected to the FlowCom.

The flow results can also be plotted on graphs. Flow software can automatically plot the data. Additional factors and relationships are discussed in Chapter "7.0 Flowbench Theory" on page 60. Specific applications are discussed in Chapter "8.0 Flowbench Applications and Techniques" on page 77.

5.7.5 Preventing Test Errors

Each test you create involves considerable effort on your part that is wasted if you allow undetected errors to creep into your test programs. Always check the following points to reduce the chances of mistakes.

1. Always use the same orifice range at the same test point.
2. Keep the leakage flow to a minimum by making a good seal on all surfaces, including the valves in the head.
3. Ensure that nothing alters the size of the testing opening when the motors are on. If light valve springs are used, make sure the valves are not sucked open by the intake test's vacuum.
4. When testing cylinder heads, always use a flow inlet guide on the intake side of the head, and always use the same guide and cylinder adapter.
5. Try to conduct your tests when there are no frequent changes in line voltage. Voltage changes do not affect the accuracy of the SuperFlow flowbench, but they will cause it to surge and become unstable.
6. As nearly as possible, conduct all tests with the same equipment, used in the same way.
7. When in doubt, repeat the tests. If you don't get the same results, start over.
8. Make sure the FlowCom agrees with the flowbench on the range, the flow direction valve, and the test pressure setting.

5.8 Test Tips

- If uncertain of which range to use, begin with all stoppers removed. Flow the test device and decrease the range until the flow scale reads above 70%.
- On flowbenches with FlowCom and a motor controller, the flow control valve for the test mode can be left wide open throughout the testing. FlowCom automatically adjusts the motor speed to maintain the desired test pressure.
- If testing cylinder heads with intake manifolds, run a series of flow tests on just the heads. Then remove the inlet air guide and replace it with the intake manifold. Repeat the flow tests and compare the results to determine the effect of the intake manifold.

Table 5-7. Temperature Difference Factor

Degrees Fahrenheit											
Temp. Diff.	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°
Intake	.996	.992	.988	.984	.981	.977	.973	.970	.966	.962	.958
Exhaust	1.004	1.008	1.012	1.016	1.019	1.023	1.027	1.030	1.034	1.038	1.042
Degrees Centigrade											
Temp. Diff.	3°	6°	9°	12°	15°	18°	21°	24°	27°	30°	33°
Intake	.997	.991	.987	.983	.980	.975	.971	.967	.963	.959	.954
Exhaust	1.004	1.009	1.013	1.017	1.020	1.025	1.029	1.032	1.036	1.041	1.047

6.0 Maintenance

6.1 Maintenance

Very little maintenance is required on a flowbench; however, it is important to keep the flowbench clean. Regular calibration is not necessary as long as you do not change or modify anything inside the flowbench, but some manufacturing users find that periodic calibration ensures product quality.

6.2 Troubleshooting

Before assuming anything is wrong with the flowbench, verify that all of the electrical and mechanical connections are intact, and perform the operation check as detailed in "4.2 Operational Check" on page 13.

If a problem with the flowbench measuring system arises, check the following:

Table 6-1. Troubleshooting

Problem	Possible Cause	Solution
The flowbench will not power on	• Power cord not plugged in • Main circuit breaker is off • Fuses in the motor controller • Cable connections on FlowCom or the motor controller • Defective FlowCom or motor controller • Defective motor switch or motors	• Check the power cord • Check the circuit breaker at the power distribution box • Go to section "6.4.1 Fuses" on page 54 • Check the cable connections on the FlowCom panel and on the motor controller box. • Contact SuperFlow Customer Service. • Go to section "6.4.2 Blower Motor Replacement" on page 54
No display on FlowCom	• Power source is not connected or is defective • Blown 1A fuse on motor controller • FlowCom or the motor controller is defective	• Check cables and power source (refer to section "5.1.2 FlowCom Connections" on page 25) • Go to section "6.4.1 Fuses" on page 54 • Contact SuperFlow Customer Service
Surging motor	• Bi-stable phenomenon due to port in head • Line voltage varying • Motor is failing • Motor controller malfunction • FlowCom PI settings may be wrong	• Perform operational check using test orifice plate (section 6.3.4, “High-flow Test,” on page 6-9. • Check incoming power. • Go to section 6.4.2, “Blower Motors,” on page 6-14. • Contact SuperFlow Customer Service. • Go to section 6.6, “Control Settings,” on page 6-17.
A Range Error message appears on the FlowCom display	• The FlowCom has been configured for the wrong flowbench model or is defective	• Contact SuperFlow Customer Service.

Table 6-1. Troubleshooting (continued)

Problem	Possible Cause	Solution
No test pressure or flow reading on FlowCom	• Pressure transducer is defective or needs calibrating	• Refer to section "6.5.4 FlowCom Calibration Options" on page 59
Flow readings are not as expected	• FlowCom not zeroed • Incorrect range setting • Excessive leakage • Improper calibration of the FlowCom	• Go to section "5.3.1 Autozero" on page 34. • Make sure the correct range is selected (refer to section "5.5 Flowbench Ranges" on page 40). • Perform the flowbench flow tests according to the procedures in section "6.3 Flowbench Flow Tests" on page 48. • Go to section "6.5 Calibration" on page 56
Test Plate in exhaust mode shows high readings while intake is normal	• The most probable cause would be a small leak in the tubing connected to the P2+ port on FlowCom.	• Repair the leak
High exhaust readings and low intake reading, or low exhaust readings and high intake readings	• Leakage around one end of the tubing connected to the P1 ports on FlowCom	• Repair the leak
Can't achieve desired test pressure	• Flowbench not capable of flowing test device • Incorrect flow range. • Leakage in bench • Failing motors	• Use a lower test pressure and convert flow rate value. • Set for correct range. • Go to section "6.3 Flowbench Flow Tests" on page 48. • Go to section "6.4.2 Blower Motor Replacement" on page 54.
Excessive leakage	• Air leaks anywhere on the flowbench can cause problems	• Perform the no-flow test according to the procedure in section "6.3.2 No-Flow Test" on page 48
The flowbench appears to have diminished capacity	• Low line voltage or defective motor or motors	• Perform the maximum capacity test according to the procedure in section "6.3.5 Maximum Capacity Test" on page 50
No communication between FlowCom and the computer	• Disconnected or defective cable • Communication port not configured properly on FlowCom or computer • Flow software is not configured properly • Communication port malfunction on computer • FlowCom malfunction	• Check cable connections • Go to "4.3 Computer Connections" on page 16

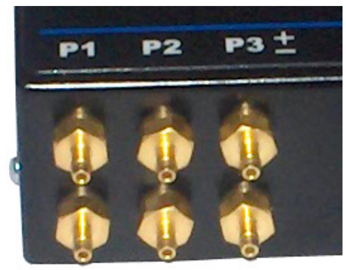
6.0 Maintenance

6.3 Flowbench Flow Tests

If the flowbench does not seem to generate the correct flow rates, you can check the bench for problems using the following tests.

For test results and solutions, see "Table 6-2. Test Results" on page 53.

6.3.1 Flow Test



1. Remove the plastic tubes from the FlowCom **P1** and **P2** ports. Make notes on where they go.
2. While monitoring the display for test pressure, gently blow or suck into the **P2** ports one at a time. Observe for a change in the reading.
3. While monitoring the display for flow pressure or flow rate, gently blow or suck into the **P1** ports one at a time. Observe for a change in the reading.

See section "5.2.4 Selecting Displayed Channels" on page 32 on how to change the channels viewed on the display.

If the readings do not change, either the FlowCom transducer has a problem or it needs to be calibrated. (See section "6.5.4 FlowCom Calibration Options" on page 59.)

Start first with restoring the saved calibration, then try the default calibration. If the pressure still fails to read, most likely the transducer is defective, requiring you to send the FlowCom to SuperFlow for repair and calibration.

4. Blow or suck gently into each tube, then block the tube with your tongue or pinch the tube tightly. Hold for at least 10 seconds. If the FlowCom reading slowly returns to zero, there is a leak around the port fittings or in the pressure transducers in the FlowCom, requiring you to send the FlowCom to SuperFlow for repair.

6.3.2 No-Flow Test

The no-flow test is basically the same as a leakage test except it checks for leaks in the bench itself.

1. Bolt the test orifice plate onto the baseplate.
2. Install all the rubber stoppers in the orifice plate on top of the flowbench leaving **#1** open. This is range **#1**.
3. Set the flow direction switch to **Intake**.
4. Place the rubber stopper in the large hole in the test orifice plate, leaving the small hole open.
5. Set the servo mode to control to test pressure (see section "5.2.6 Setting the Servo Mode" on page 33).
6. Set FlowCom flow range to **Intake, Range 1**.
7. Set FlowCom test pressure to **10 inH$_2$0 (25 cm)** according to the procedure in section "5.2.2 Setting the Test Pressure" on page 30.

8. Set FlowCom leakage to **0** (zero) according to the procedure in section "5.2.5 Leakage" on page 32.
9. Set the flow control valves:
    - Close (CW) the exhaust valve and fully open (counterclockwise, CCW) the intake valve.
10. Switch the motors on and let the airflow stabilize.
11. Place your finger over the small hole in the test orifice plate.
    - The flow reading should settle back to near zero with the flowbench running. This is the normal leakage of the flowbench itself, and a small amount is acceptable. If there is no leakage, it is possible that the test pressure may not be able to maintain at a stable reading.
12. Record the flow meter reading and turn off the motors.
    - If the leakage exceeds 3 cfm (1.5 lps), record the flow meter reading and try to locate the source of the leak.
    - Perform the test again after a leak is repaired.

    TIP: Press the **LEFT ARROW** key on FlowCom to hold the reading. Record the data, then press the **RIGHT ARROW** to resume active readings.
13. Repeat this test on exhaust if desired. However, in most cases a leak in the flowbench is always detected in intake mode.

Potential Sources for Leaks

- Leakage around the base plate. This adds to flow readings' intake mode and reduces the exhaust readings (most obvious at very low flow).
- Leakage around the orifice plate at the top of the flowbench. This has the opposite effect from leakage around the baseplate (most obvious at very low flow).
- Leakage in the plastic tubes. Remove the back panel and carefully check all the tubing, particularly around the switching valve.

6.3.3 Low-Flow Test

Perform the same test as above, except leave the *small* hole in the **test orifice plate** open. Record the flow reading. It should be approximately 4.5 cfm at 10" test pressure. Flow in excess of **+1 cfm (0.5 lps)** of this reading could indicate a leak around the test plate or the baseplate.

6.3.4 High-Flow Test

The high-flow test checks the accuracy of the flowbench using the **Test Orifice Plate**.

1. Bolt the test orifice plate onto the baseplate leaving both holes open.
2. Remove all the rubber stoppers in the orifice plate on top of the flowbench leaving stopper in the hole **#4**. This is range **#8**.
3. Set the servo mode to control to test pressure (see section "5.2.6 Setting the Servo Mode" on page 33).

4. Set FlowCom flow range to **Intake, Range 8**.
5. Set the test pressure to **10 inH20 (25 cm)** according to the procedure in section "5.2.2 Setting the Test Pressure" on page 30.
6. Set the leakage to **0** (zero) according to the procedure in section "5.2.5 Leakage" on page 32.
7. Set the flow control valves:
   - Close (CW) the exhaust valve and fully open (counterclockwise, CCW) the intake valve.
8. Switch the motors on and let the airflow stabilize.
9. Observe and record the flow reading. It should match the value stamped on the test plate (±3 cfm) or be approximately 150 cfm.

   TIP: Press the **LEFT ARROW** key on FlowCom to hold the reading. Record the data, then press the **RIGHT ARROW** to resume active readings.
10. Turn off the motor switch and close the intake flow control.
11. Repeat the test in **Exhaust** mode.

6.3.5 Maximum Capacity Test

> **⚠ WARNING**
>
> 
>
> **The motors on the flowbench run at full speed during this test. Wear appropriate ear protection.**

Flowbench capacity can be affected by such factors as low line power, defective motors, a malfunctioning motor controller, excessive leakage, and the local elevation. This test determines the maximum flow capacity of the flowbench.

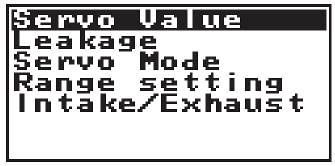
When testing for maximum capacity, it is important to know that the flowbench flow in rate cannot be read directly from the FlowCom. Flow *pressure* must be used instead and mathematically converted to *Flow cfm*. This is necessary because the FlowCom calculates what the flow *would be* if the test pressure set point were reached.

Since we are setting the flowbench for an unrealistic test pressure set point well above its rated capacity *and* want to know the **actual** flow (not the **predicted** flow), follow the procedure below to test for maximum capacity.

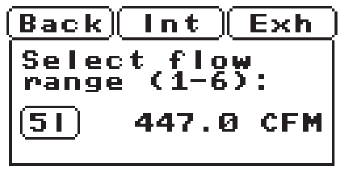
1. Remove any fixtures from the flowbench leaving only the large hole in the baseplate open.
2. Acquire a steel plate slightly larger than the baseplate opening to use for restricting the opening in the baseplate.
3. Remove all the rubber stoppers in the orifice plate on top of the flowbench (range **#9**).
4. Set the FlowCom to control to test pressure according to the procedure in section "5.2.6 Setting the Servo Mode" on page 33.
5. Set the bench flow direction switch to **Intake**.
6. Obtain the **Max Range Value** for range **9**. This information is on the calibration sheet shipped with the flowbench or can be read from the FlowCom using the following procedure.

6.0 Maintenance

- Press **F3 (Test)** on the FlowCom panel. The **Test** menu appears.



- Use the **DOWN ARROW** button to scroll to **Range Setting**. Press **ENTER** button ( ). The **Select Flow Range** screen appears.



- Press the **F2 (Intake)** or **F3 (Exhaust)** buttons to select the flow direction. Press the **UP** or **DOWN ARROW** buttons to scroll to the desired range. The full-scale flow reading for that range and direction displays on the screen. Press **F1 (back)** to return to the previous screen. Press any of the **F** buttons to return to the current data screen.

7. Set FlowCom flow range to **Intake, Range 9**.
8. Set **Leakage** to **0** according to the procedure in section "5.2.5 Leakage" on page 32.
9. Set the FlowCom to display **Test Pressure** and **Flow Pressure** according to the procedure in section "5.2.3 Setting the Units of Measurement" on page 31.
10. Set the **Test Pressure** for **25 inH$_2$0**.

NOTE: Always enter a value higher than what the flowbench can reach with the test orifice wide open. In this test the high test pressure set point cannot be met because the hole in the baseplate is too large.

---

11. Open (CCW) the **intake** flow control valve fully and close (CW) the **exhaust** control valve.
12. Turn the motors on. The motors will run at 100% trying to reach the high test pressure set point.
13. Place the steel plate on the baseplate hole so that it barely restricts the flow.

> **⚠ CAUTION**
>
> **Do not leave anything loose on the baseplate or it may be sucked into the flowbench motors.**

14. Slowly move the plate in to restrict the flow while watching the pressure readings. Notice that test pressure slightly increases and the flow pressure decreases as the test orifice size is reduced.
15. Continue to restrict the flow until the test pressure reaches **10 inH$_2$0**.
16. Record the flow pressure.
17. Turn OFF the motors.

6.0 Maintenance

18. To convert the flow pressure measurement into flow in cfm, use this formula:

$$\textbf{cfm} = \sqrt{\mathbf{P}/\mathbf{14.5}} \times \textbf{MaxRangeValue}$$

Where:

- **cfm** = Flow rate in cubic feet per minute
- **P** = The flow pressure value recorded
- **14.5** = Maximum pressure drop across the test orifice
- **MaxRangeValue** = The full-scale range value for your specific bench obtained in step 6.

This is the maximum flow capacity of the flowbench at 10 inH_20.

Example:

If the Max Range Value for Range 9, Intake on your bench = 280.0 and you measured a Flow Pressure of 14.0 in/H_2O at 10 inH_2O test pressure, then:

Maximum Capacity **=** $\sqrt{\mathbf{14.0}/\mathbf{14.5}} \times$ **280 = 275.1(cfm)**

⚠ CAUTION
If desired, you may perform this test with the flowbench direction set to Exhaust. However, this is dangerous because it is extremely difficult (if not impossible) to hold down the restriction plate to the top of the flowbench baseplate. If this test must be done in exhaust mode, loosely bolt two plates together. Insert one of the plates underneath the baseplate with the other on top. Tighten the bolts enough to secure the plates but still allow them to slide. Be absolutely certain the plates will not be expelled from the flowbench when the motors are turned on.

6.3.5 Test Results

Test Results

The problems and solutions below may not apply to all situations. If necessary, collect the recorded data from the flow tests and contact SuperFlow Customer Service for assistance.

Table 6-2. Test Results

Problem	Solution
Excessive Leakage with test plate holes blocked	• Locate the source of the leak—the most likely area is somewhere around the baseplate
The flow rate for the test plate does not agree with the value on the test plate label	• An incorrect leakage value is entered in the FlowCom—perform a leak test • Excessive leakage around the test plate—perform a leak test • The test is being conducted at a test pressure other than where the flowbench was calibrated (SuperFlow SF-260 flowbenches are typically calibrated at 10 inH_2O) • Incorrect calibration in the FlowCom—perform the calibration procedure for the P1 and P2 pressure transducers • Incorrect Full-Scale range values entered in the FlowCom
The flowbench capacity is significantly reduced	• One or more blower motors are defective (go to section "6.4.2 Blower Motor Replacement" on page 54) • Blockage around the vents on the sides of the flowbench cabinet • Line voltage is too low • Leaks in air tubing • The motor controller is malfunctioning

6.0 Maintenance

6.4 Service

6.4.1 Fuses

No fuses or breakers are within the cabinet. The motor controller has two fuses, they are:

- **15A:** Motor protection
- **1A:** FlowCom protection

⚠ CAUTION

Disconnect the main power to the flowbench before changing fuses.

TIP: Always use an ohmmeter or continuity tester to verify the fuses are not blown. A visual inspection is not 100% valid.

If the cable and fuses check out, you are sure you have correct voltage, and you are sure that everything is connected properly but the FlowCom still doesn't power on, then it may be necessary to send the FlowCom and motor controller units to SuperFlow for repair.

6.4.2 Blower Motor Replacement

The SF-260 has four (4) 110-VAC blower motors in it to provide airflow. Two (2) motors are used for intake flow and the other two (2) are for exhaust flow. The motors are wired in parallel to allow for 110VAC operation. If you must replace a motor, SuperFlow advises replacing its mate as well. Sometimes when a motor fails, it will cause the other motor paired with the defective one to draw more current and quicken its failure.

Checking the Motors

1. Remove all the rubber stoppers from the upper orifice plate.
2. Look down through the largest orifice on top of the bench while using the flashlight to illuminate the motors at the bottom of the chamber.
3. Verify that the motor connections are still in place on the lugs and the connections between the motors are not burnt or discolored.

NOTE: It may take some creative solutions to get them back into place if any of the connections are loose or not fully engaged.

4. To verify the motors' operation, mount the test orifice plate to the baseplate and place the bench in the **Intake** mode.
5. Remove all the stoppers from the orifices on top of the bench.
6. Turn on the bench and look down through the orifices on top. Try to ascertain whether one motor is sparking more than the other.
7. Now take the flashlight and try to ascertain whether both motors are spinning at the sametime. Repeat the process in **Exhaust** mode.

6.0 Maintenance

Replacing a Motor

There is no easy access to the motor chamber. The back panels on the flowbench are sealed to prevent any air leakage (excessive leakage in the flowbench reduces capacity and accuracy). Irreparable damage can occur if these panels are not carefully removed.

If it is necessary to replace a motor, the best option is to send the flowbench to SuperFlow Customer Service where trained technicians have the proper skills and tools for this operation.

In some cases the damage is so extensive that the only option is to transfer the FlowCom, motor controller, and other external components of the flowbench to a new cabinet with new motors.

6.4.3 Temperature Probes

Two air-temperature probes are used with FlowCom to provide automatic temperature correction and motor overheating protection. One is in the chamber under the test orifice baseplate, and the other is at the top of the cabinet just below the upper orifice plate (see "Figure 4.1: SF-260" on page 11). No maintenance is necessary for the probes; replace only if they are defective.

When used with the electronic temperature sensors, the FlowCom is programmed to display a warning if the temperature on either one reaches 190°F and shuts the motors off if the temperature exceeds 216°F.

Figure 6.5: Temperature Sensors

Verify the probes by observing the **Temp 1** and **Temp 2** channels on the FlowCom display. If the flowbench has been off for several hours, both readings should be the same and at room temperature.

The probes can be replaced by loosening the compression fitting and removing the probe. Insert the replacement probe and tighten the fitting. Plug the connector into one of the temperature inputs on the FlowCom side panel (see "Figure 4.2: FlowCom Connections" on page 11). FlowCom uses the probes for a difference calculation and monitors both probes for motor overheating, so it does not matter which input is used.

6.5 Calibration

Calibrating a SuperFlow flowbench involves a two-step process. First, calibrate the pressure reading devices; then determine the full-scale flow readings for each range.

NOTE: Regular calibration is not necessary as long as you do not change or modify anything inside the flowbench, but some manufacturing users find that periodic calibration ensures product quality.

6.5.1 Pressure Sensor Calibration

The pressure transducers in the FlowCom can be periodically calibrated for highest measurement accuracy. The FlowCom enclosure contains four pressure transducers: test pressure, flow pressure, velocity pressure, and barometric pressure.

WARNING

DO NOT try to recalibrate the FlowCom sensors unless you have an accurate pressure source or barometric pressure data.

Because calibration standards are the basis for accurate test results, never guess at the accuracy of the standard. As a rule, the source used to calibrate a sensor should be at least 10% more accurate than the sensor being calibrated. For example, if a sensor has an accuracy of ±1%, the standard used to calibrate it should have an accuracy of ±0.1%.

The pressure transducers used in the FlowCom have an accuracy of better than ±0.5%. Therefore, unless you have access to a very high-quality pressure calibrator, the accuracy of your FlowCom after calibrating it will be no better than the standard you use.

To calibrate the Test, Flow, and Velocity pressure channels, use an accurate pressure source that reads in inches of water (inH_2O).

Test, Flow, and Velocity Pressure Channels

Calibrate the Test, Flow, and Velocity pressure channels (1–3) using an accurate pressure source that reads in inches of water (inH_2O).

1. Set the FlowCom display to show the three pressure channels (refer to section "5.2.4 Selecting Displayed Channels" on page 32).
2. First, check for any internal leakage inside the FlowCom box where the plastic tubes connect the external ports to the internal pressure transducers.

IMPORTANT

FlowCom is powered by a motor controller, the automatic zeroing of the pressure transducers must be disabled during the calibration process. If actually performing a calibration, the autozero is turned off when the calibration menu on FlowCom is accessed. If just checking the pressure readings without calibrating, the autozero function can be turned off through FlowCom. See section "5.3.1 Autozero" on page 34 for information on how to do this.

- Connect a piece of tubing to one of the pressure ports on the FlowCom side panel.
- Blow or suck on the open end of the tubing to get a reading on the FlowCom display, then block the end of the tubing with the tip of your tongue or pinch the tube to hold pressure.
- Observe the readings for at least 10 seconds to determine whether an internal leakage exists.
- Repeat for each pressure port.

3. Connect the pressure calibrator or standard to the positive (+) port of the desired channel on the FlowCom side panel.
   - **Flow Pressure:** P1+, Channel 1
   - **Test Pressure:** P2+, Channel 2
   - **Velocity Pressure:** P3+, Channel 3

   If using a pressure source (such as an air pump), connect the three together with a tee fitting.
4. Press **F2 (Cal)** on the FlowCom panel.
5. Use the **UP** or **DOWN ARROW** buttons, select **Calibrate** and press **ENTER** button (↵).
6. Enter **3512** as the password.
7. Use the **UP** or **DOWN ARROW** buttons to select a channel.
8. Press **ENTER**.
9. Follow the screen instructions. Use "Table 6-5. NFS Values" for the Near Full-Scale (NFS) values.

Table 6-5. NFS Values

P1 Flow Pressure	P2 Test Pressure	P3 Velocity
10" H_2O	15" H_2O	15" H_2O

10. Save the calibration by pressing **Backup Cal** (see section "6.5.4 FlowCom Calibration Options" on page 59).
11. Press **Back** to exit the Calibrate menu.
12. Press any of the **F** buttons to return to the current data screen.

Barometric Pressure Calibration

The barometric pressure sensor is installed on the Printed Circuit Board (PCB) inside the FlowCom box. The channel for Baro Pressure was calibrated at the factory before the flowbench was shipped. If desired, it can be calibrated to provide more accurate readings for the actual flowbench location.

Obtain an accurate, uncorrected barometric pressure reading in inches/Hg from a mercury barometer. If a mercury barometer is not available, contact a local airport or weather service and ask for the “station or uncorrected pressure.” The barometric pressure reading from a television station is corrected for local elevation and therefore is not acceptable for calibrating the sensor.

1. Press the **F2 (Cal)** button to access the **Calibration** menu.
2. Use the **UP** or **DOWN ARROW** buttons to scroll to **Calibrate**.
3. Press **ENTER** button (↵).
4. Type **3512** as the password.
5. Select **Baro** (channel **4**) to calibrate.
6. Enter the uncorrected current barometric pressure.

7. Press **Back** to exit the Calibrate menu.

8. Press any of the **F** buttons to return to the current data screen.

TIP: As a rule, you can take the barometric pressure from the local television or radio station and subtract 1 inch of mercury for every 1000 feet of elevation to get the station pressure. It will not be accurate but will be close.

6.5.2 Flow Calibration

Full-scale flow values for each range on a SuperFlow flowbench is determined by the use of a set of flat plates with sharp-edged orifices bored (not punched) to specific sizes. The flow data on these orifice plates are based on known engineering and national standards. Following sound procedures and accepted engineering practices with these calibration orifices will typically produce repeatability results of ±0.5% or better.

The flow calibration process involves flowing each test plate in various ranges and recording the data. The resultant data is used to derive the full-scale value for each range on the flowbench. This information is placed on the label affixed to the flowbench where it is used to convert flow percentage readings to cfm or lps. The full-scale range values are also entered into the FlowCom where it is used to correctly calculate flow.

The flowbench was calibrated at the factory using 10"H_2O test pressure. Unless drastic changes were made to the flowbench, it should never need re-calibrating (changing a motor does not require a new calibration). However, if calibration is deemed necessary, a calibration kit is available from SuperFlow Customer Service.

To obtain the flowbench calibration kit., contact SuperFlow Customer Service.

6.5.3 FlowCom Range Calibration

In order for the FlowCom to accuracy display the flow rates from the flowbench, the calibrated full-scale range values for the flowbench must be entered in the FlowCom memory. Every SF-260 flowbench was calibrated at the factory and a calibration sheet provided with the flowbench. This sheet is normally attached to the flowbench front panel in the upper right corner just below the light. If the flowbench was re-calibrated (see section "6.5.2 Flow Calibration" on page 58), SuperFlow provides a new calibration sheet.

To enter new calibrated range values into FlowCom, or to verify what is entered:

1. Press the **F1 (Conf)** button.
2. Use the **UP** or **DOWN ARROW** buttons to highlight either **Intake F.S.** or **Exhaust F.S.** and press the press **ENTER** button (↵).
3. Type **3512** as the password.
4. Enter or verify the range values for all six ranges. Be sure to enter the engineering units as **CFM**.
5. After entering all six ranges, press the **F2 (Save)** button.
6. Press the **F1** button to return to the FlowCom main menu.

7. If changes were made, power off the FlowCom, wait 30 seconds, then power it back on. This ensures the new calibration is activated.
8. Perform the operational test according to section "4.2 Operational Check" on page 13.

6.5.4 FlowCom Calibration Options

The FlowCom calibration can be saved in memory. Once saved, the calibration can be restored to the saved values in the event the current calibration is defaulted or altered.

1. Press the **F2 (Cal)** button to access the **Calibration** menu.
2. Use the **UP** or **DOWN ARROW** buttons to scroll to desired option.
   - **Calibrate:** Accesses the sensor calibration option (see section "6.5.1 Pressure Sensor Calibration" on page 56).
   - **Default Cal:** Sets the calibration of the pressure transducers to the factory defaults. These are typical average values and may not be accurate for any particular flowbench. Default the calibration only prior to performing an actual calibration or with instructions from a SuperFlow Technical Support representative to do so.
   - **Backup Cal:** This option saves the current calibration values for the pressure sensors to memory, overwriting any previous values stored in memory.
   - **Restore Cal:** This option recalls the calibration values stored in memory and activates them.
3. Press **ENTER** button ( ).
4. Type **3512** as the password.
5. Use the **LEFT ARROW** button to select **Yes**.
6. Press **ENTER**.
7. Press any of the **F** buttons to return to the current data screen.

7.0 Flowbench Theory

7.1 Flow Testing

7.1.1 Introduction

Many of the applications of flowbenches and the data they provide are often set apart from normal data because of the mystique associated with flowbenches and flow testing.

An air flowbench is essentially a device that measures the resistance of a test piece (cylinder head, manifold, carburetor, throttle body, exhaust systems, etc.) to flow air. Many different designs and models are on the market today that allow the user to compare flow results before and after changes in the flow path.

7.1.2 What Is A Flow Test?

In its simplest form, flow testing consists of blowing or sucking air through a component at a constant test pressure. Then the flow rate is measured. A change is made and then the component is retested. Greater airflow indicates an improvement. If the tests are made under the same conditions, no corrections for atmospheric conditions or machine variations are required. The results may be compared directly.

For more advanced tests, it is possible to adjust and correct for all variations so test results may be compared to those of any other device, tested under any conditions, or tested on any other SuperFlow flowbench. Further calculations can be made to determine valve efficiency and various recommended port lengths and cam timing on a cylinder head. Other calculations can be used on other devices.

7.1.3 Flowbench History[1]

1. Written by Harold Bettes II.

Flowbenches and airflow data have been part of the internal combustion engine development cycle for design, research and development for many years. Some of the first engine airflow studies (using some type of flow testing) date back to the early 1900s. However, the study of engine airflow and flowbench information and the relationship to performance has only been commonplace in the racing industry since the late 1960s.

The foundry process and the associated compromises actually controlled most early cylinder head and manifold designs. These manufacturing compromises drove most designs—not the technical aspects or specific airflow requirements.

When SuperFlow Corporation introduced the first portable flowbench to the engine builders of the world in 1972, airflow science came to kitchen tables, shops, and garages everywhere. More elaborate and complex benches had been around for some time when the first SuperFlow model was made available, but never in such an easy-to-use configuration. As market demand and understanding grew, many larger models were made available as racers everywhere began to compare flow information. Thousands of benches are in use every day, and engine component airflow technology is growing rapidly.

The various test pressures in use in the field are interesting because they were derived as a historical reference more than a technical requirement (see section "8.1 Test Pressures and Comparing Flow Numbers" on page 77).

The first airflow benches in use at the Original Equipment Manufacturer (OEM) level were expensive, cumbersome, and complex machines that were applied in the late 1960s and early 1970s for some specific engine airflow development work. Oldsmobile and Pontiac used flowbench-guided designs early on;

however, Chevrolet did not have a flowbench lab in use until the 1970s. American Motors used flowbench-guided cylinder head designs in the early 1970s as well. Chrysler adapted a flow lab from elements that were used in air filter work, and the lab was developed in parallel with their introduction of the 426 Hemi engine. The Ford Motor Company flow lab dates to the mid-1960s where they supported their winning LeMans racing effort with their GT40 racing vehicles.

Some of the OEM, specialty-engine manufacturers, and professional race teams are now using Computational Fluid Dynamics (CFD) to assist in Computer-Aided Design (CAD) and flowbenchdriven designs. Many of the OEMs have abandoned their in-house airflow benches to outsource much of their airflow development testing. As a result, some well-established shops using SuperFlow or other flowbenches around the country typically get involved in OEM development contracts because the programs are more cost and time effective.

7.2 Airflow through Engines

The power of an engine is directly proportional to the amount of air drawn into the cylinder and retained until ignition occurs. By reducing the airflow resistance of the intake and exhaust tract, cylinder filling improves and engine power increases directly. The average airflow through each engine cylinder can be estimated as:

Average airflow (cfm) = 1.67 x HP per cylinder

Average airflow (l/s) = 1.06 x kW per cylinder

The maximum intake airflow rate for a single cylinder is about 2.5 times the average airflow for the cylinder because the intake occurs during only 40% of the total cycle.

Example:

If a Chevrolet V-8 engine produces 440 horsepower (hp), the power per cylinder is 55 hp.

Average airflow = 1.67 x hp = 92 cfm (43.4 l/s)

Avg. Intake Rate = 2.5 x 92 cfm = 230 cfm (108 l/s)

Peak Intake Rate = 2.5 x 230 cfm = 575 cfm (271 l/s)

When an engine is operating, the pressure drop across the cylinder head ranges from 0 up to about 200” (500 cm) of water at the 575-cfm (271-l/s) flow rate. (This is equivalent to the test pressure reading on the SuperFlow flowbench).

The average pressure drop is about 25” of water, 2" of mercury, or 63 cm of water at the 230-cfm (108-l/s) flow rate. When testing with the SuperFlow flowbench, it is not important whether a test pressure of 100, 50, or 25 is used, provided the same pressure is used for each subsequent test to compare to the original test. A head that measures 10% better at 50 will also measure 10% better at 25, 10 or 5, or 3 (refer to "Table 7-1. Minimum Recommended Test Pressures at Low Valve Lift" on page 62).

The exception to this rule is at lower valve lifts or through small, long passes. Then the test pressure must be kept above a certain minimum to ensure the flow remains turbulent and does not slow down and become laminar.

7.0 Flowbench Theory

Table 7-1. Minimum Recommended Test Pressures at Low Valve Lift

Minimum Valve Lift	Minimum Test Pressure
.050” (1.2 mm)	15” (38 cm) water
.100” (2.5 mm)	8” (20 cm) water
.200” (5.0 mm)	5” (13 cm) water
.300” (7.5 mm)	3” (8 cm) water

Conveniently, the bigger the opening, the lower the required minimum test pressure. Presently in the United States, most carburetors are rated in flow capacity at a test pressure of 20.4” of water (1.5” of mercury, 51.8 cm of water). An 850-cfm (400-l/s) carburetor is one that passes 850 cfm (400 l/s) of air at a test pressure of 20.4” (51.8 cm) of water. However, if you observe a manifold vacuum gauge on a racing engine at full throttle, notice that it only reads approximately 0.5” of mercury (6.8” or 17 cm of water). At a test pressure of 6.8” (17 cm) of water, the same carburetor would only pass 490 cfm (230 l/s) of air. This is why carburetor ratings appear to be out of proportion to engine requirements. Carburetors may be tested and compared on the flowbench, but sometimes only at a reduced test pressure. At a test pressure of 1" (2.54 cm) of water, the carburetor will flow 22% of its rated capacity at 1.5” of mercury. For example, at 1" (2.54 cm) of test pressure, a 660 cfm carburetor will flow 0.22 x 660 = 145 cfm.

The amount of power gained by improved airflow depends upon the engine’s volumetric efficiency (the percentage the cylinder is full). An engine with 60% volumetric efficiency can be improved more than an engine with 90% volumetric efficiency.

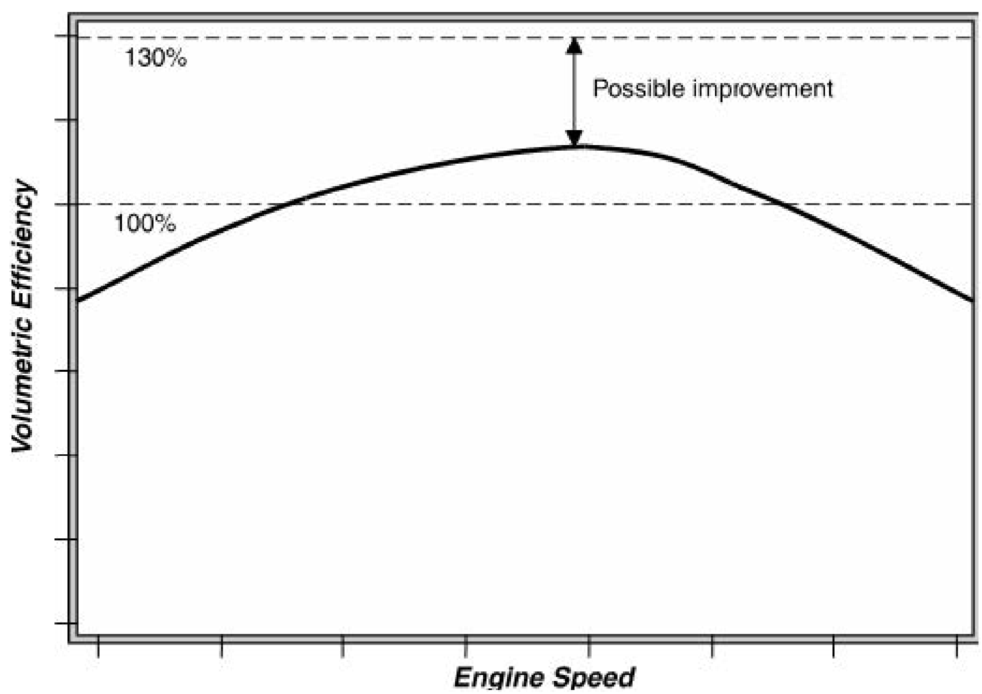


Figure 7.1: Volumetric Efficiency versus Engine Speed

Estimated Volumetric Efficiency for Gasoline-burning Engines

Volumetric Efficiency = 5,600 x hp x 100% / (rpm x CID)

Volumetric Efficiency = 123 X kW x 100% / rpm x liters)

CID is the cubic inch displacement of the engine. Be sure to use accurate power figures. If the volumetric efficiency on an un-supercharged engine exceeds 130%, the power or revolutions per minute (rpm) figures are probably in error.

Estimated Volumetric Efficiency For Alcohol-burning Engines

Volumetric Efficiency = 4750 x HP x 100% / (rpm x CID)

Volumetric Efficiency = 104 x kW x 100% / (rpm x Liters)

7.3 Power, Speed, and Flow Relationships

Power, rpm, displacement, and engine airflow capacity are all related in a definite fashion. With the widespread use of accurate engine dynamometers and flowbenches, it is possible to measure the airflow potential of an engine and predict its maximum potential power and the rpm at which the power will peak. You can anticipate in advance the effect of porting and manifold changes and make proper camming changes to take full advantage of the differences. The total airflow through a gasoline engine determines its maximum potential power. At peak power, a racing engine will use 1.67 cubic feet of air per minute (cfm) for each horsepower it develops. For example, a 100-horsepower engine will use 167 cfm. This is true for any four-cycle gasoline-burning racing engine. Alcohol-burning engines will use 1.47 cfm per horsepower developed.

Estimated Engine Airflow

Gasoline, naturally aspirated cfm = 1.67 x hp

Gasoline, naturally aspirated l/s = 1.06 x kW

Alcohol, naturally aspirated cfm = 1.47 x hp

Alcohol, naturally aspirated l/s = 0.93 x kW

To increase the engine power output, you must increase the airflow capacity of the engine or burn the air/fuel charge more effectively. In the past, racers have concentrated primarily on increasing the airflow. To move more air through an engine, you must reduce the flow resistance of the carburetor, injector, intake manifold, and cylinder head. This need has led to hundreds of aftermarket carburetors, manifolds, and ported cylinder heads—all designed to move more air through the engine.

The flowbench is a device designed to measure the airflow capacity of various engine components. Air is blown or sucked through the intake system at a standard pressure, and then the airflow capacity is measured. In this manner, different parts can be compared and the effect of changes quickly evaluated.

These flow tests are conducted at a constant peak air velocity at the valve, usually between 100 and 400 feet per second (30 to 120 m/s).

While the flowbench air velocity does not vary as it does in an operating engine, experiments show that flowbench tests actually simulate engine operation closely enough. This is why flowbenches are now a major development tool for engine manufacturers and racers alike. What is the relationship between the capacity on the flowbench and the power of the engine? Tests show that if the complete intake system airflow is measured at maximum valve lift, a well-developed racing engine will produce the following power per cylinder:

Calculated Engine Power from flowbench Test Flow

HP = 0.27 x (Corr. Test Flow cfm) x (25 / Test Pressure inches) 0.5

kW = 0.44 x (Corr. Test Flow l/s) x (60 / Test Pressure cm) 0.5

To reach this power level, the engine must also have the maximum compression, the right cam, and a tuned exhaust system. In short, it must be a well-tuned racing engine. With this formula, a head-porter can see that improving the maximum flow through the intake system by 1 cfm at 25” of water test pressure will gain the engine 0.27 horsepower per cylinder. (The formula is only for gasoline four-stroke engines without super-chargers).

The intake system flow also determines the engine speed at which the engine will develop peak power:

Calculated Engine Speed for Peak Power from Flowbench Test Flow

rpm = 1265 x (Corr. Test Flow cfm) x (25 / Test Pressure inches)0.5 / CID per cylinder

rpm = 45,200 x (Corr. Test Flow l/s) x (60 / Test Pressure cm)0.5 / cc per cylinder

The engine displacement is *per cylinder*. For super-stock engines and engines that are not all-out racing engines, peak power may occur at 10% higher rpm than the above formula indicates.

If you have a 220-horsepower, small-block 292 Chevy which runs in super-stock, determine what the maximum power will be and at what rpm. Tests show that at a test pressure of 25" (60 cm) of water, this intake system will flow 166 cfm (75.8 l/s) of air. The Cubic Inch Displacement (CID) per cylinder is 1/8th of 292, or 36.5 CID (600 cc).

HP = 0.27 x 166 cfm x (25/25)0.5 = .27 x 166 x 1.0 = 44.8 HP

kW = 0.44 x 75.8 l/s x (60/60)0.5 = 0.44 x 107.2 x 1.0 = 33.3 kW

Or for all eight cylinders:

HP = 8 x 44.8 = 358.4 HP

kW = 8 x 33.3 = 266.4 kW

The rpm for maximum power will be (multiply by 1.1 for super-stock engines):

rpm = 1265 x 1.1 x 166 cfm x (25/25)0.5 / 36.5 in3= 6290 rpm

rpm = 45,200 x 1.1 x 75.8 l/s x (60/60)0.5 / 600cc = 6280 rpm

The engine has a maximum potential of 359 hp (266 kW) at 6280 rpm. Remember, this is the *maximum* potential power. The engine will only approach this level if everything else is optimized.

7.0 Flowbench Theory

"Table 7-2. Small-block Chevy 302 Engine Performance" shows how changes in the intake system will affect the engine's performance on a small-block Chevy 302 with a displacement of 37.75 CID per cylinder.

Table 7-2. Small-block Chevy 302 Engine Performance

Head	Intake System Flow @ 25" or 60 cm	Power Produced
Stock, 2.02" valve	190 cfm (89.7 l/s)	413 hp (308 kW) @ 6360 rpm
Normal ported, 2.02" valve	226 cfm (106.7 l/s)	492 hp (367 kW) @ 7570 rpm
Best ported, 2.02" valve	253 cfm (119.4 l/s)	550 hp (410 kW) @ 8470 rpm
Westlake, 2 x 1.5" valve	288 cfm (135.9 l/s)	602 hp (449 kW) @ 9270 rpm

The “normal ported” head is about the best that can normally be achieved, even with careful flowbench testing. However, it is possible to improve the head to the “best ported” level, though welding or after-market heads may be required.

For the last two heads, the engine must be wound up to 8500 and 9300 rpm to take full advantage of the additional flow. If the engine must hold together for more than a couple of runs down the drag strip, the peak power should not be developed at an average piston speed in excess of 3700 feet per minute (18.8m/s). If only a few runs down the strip are acceptable, you may raise this limit to 4600 feet per minute (23.4m/s), but the engine will need superior internal parts to last even one run.

These rules can be reduced to a simple formula for the rpm for peak power (remember, your shift points may be 10% or more above the speed for peak power):

Maximum Safe Engine Speeds

Safe peak power rpm = 22,000/inch stroke

Safe peak power rpm = 558,800/mm stroke

Maximum peak power rpm = 27,600/inch stroke

Maximum peak power rpm = 701,040/mm stroke

Returning to the example of the 302 engine, a well-ported head would be adequate for most road race applications for the 302 because the peak power is already being developed at slightly more than the 3800 fpm (19.3 m/s) piston speed. If the power peak was pushed to an even higher rpm, the engine would frequently fail to finish the race.

To take full advantage of the extra breathing of the Westlake four-valve head, the power peak would need to be at 9270 rpm (4630 fpm) and engine life would be short. Without super internal parts, it would probably not survive even one run down the drag strip because the shift point would be up around 10,500 rpm which is high for any Chevy.

By pulling all the formulas together, it is possible to construct a graph for determining the maximum intake system flow required for a particular engine and application. Use the graphs on the following pages to select the required flow for any engine and speed.

NOTE: Remember that the flow, displacement, and power figures are for each cylinder—not the entire engine.

7.0 Flowbench Theory

To use the graph, determine the displacement per cylinder of your engine, then read the speed required for any particular power and the flow capacity required on the flowbench at a 25” (60 cm) test pressure.

It is not enough to calculate the flow capacity required: the engine must achieve it. "7.4 Intake Port Area and Shape" discusses how to improve the engine airflow and judge the flow potential of any engine.

7.4 Intake Port Area and Shape

For maximum flow, the ideal intake system would have a single carburetor or injector per cylinder with a slide-plate throttle and a venturi equal to 0.85 times the intake valve diameter. Below the venturi, the carburetor bore should gradually open to the size of the intake valve at the intake manifold entrance and gradually taper down to about 0.85 times the intake valve diameter at a point approximately ½" (12 mm) above the valve seat.

The optimum length for the port is discussed in section "7.7.1 Valve Flow Potential at Various Test Pressures" on page 71.

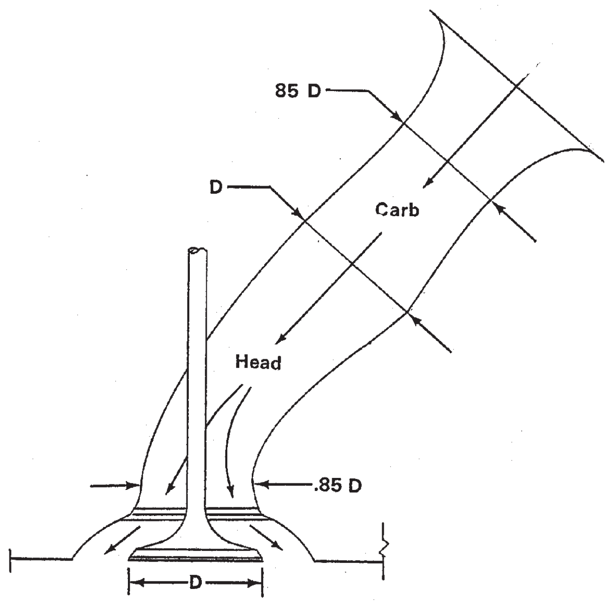


Figure 7.2: Intake Port

In practice, this ideal is never achieved, but it does provide a guideline for what an efficient port should resemble.When porting a cylinder head for maximum flow, keep these points in mind:

1. Flow losses arise from changes in direction and decreases in velocity (bends and expansions in the port).
2. Port area should be between 65% and 100% of the valve area.
3. Remove material primarily from the outside of port bends, not the inside. This improves the airflow by increasing the radius of the bend.

4. Port length and surface finish are not important to flow.
5. The greatest flow loss in the intake port is due to the expansion of the air out of the valve. This makes the area from ½" (12 mm) below the valve to ½" above the valve the most critical part of the port.
6. The valve seat shape has a substantial effect on the flow.

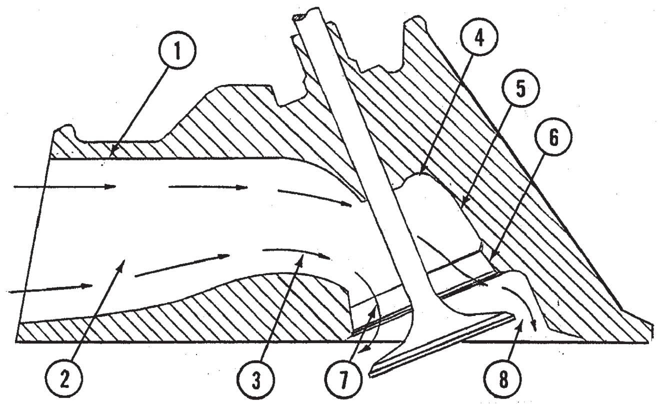


Figure 7.3: Exhaust Port

Because flow losses are caused by port expansions and not contractions, the port should be necked down above the valve seat because the air must turn 90 degrees and simultaneously expand as it flows out of the valve into the engine cylinder. Humping the port inward just above the seat allows the air to make the turn outward toward the valve edge more gradually, reducing the total flow loss. Unfortunately, many stock ports are too large in this area already.

"Table 7-3. Flow Loss" shows approximately where the flow losses occur in a stock Chevy head with a 1.94" (49.3 mm) diameter intake valve. Note that the flow losses are negligible in the straight part of the port where it is easy to grind.

Table 7-3. Flow Loss

Figure #	Source of Flow Loss	% of Loss
1	Wall friction	4%*
2	Contraction at push-rod	2%
3	Bend at valve guide	11%
4	Expansion behind valve guide	4%
5	Expansion, 25 degrees	12%
6	Expansion, 30 degrees	19%
7	Bend to exit valve	17%
8	Expansion exiting valve	31%
	TOTAL	100%

* For sand cast surface; 3% for polished surface.

7.0 Flowbench Theory

As manufactured, this head flows about 83% of its potential for a wedge combustion chamber head. The best head porters are able to increase the flow to approximately 95% of its potential with the aid of careful flow testing.

Further improvements are difficult without major adaptation and welding. Grinding and enlarging the first 2.5” of the Chevy port (which is easy to reach) has very little effect.

7.5 The Valve Seat

The valve seat has three purposes:

- Seal the port
- Cool the valve
- Guide the air through the valve

Sealing and cooling are promoted by a fairly wide seat between 0.060" (1.5 mm) and 0.100" (2.5 mm). Maximum flow is frequently achieved with a narrower seat, usually around 0.030" (.75 mm) wide.

Multiple-angle to fully radiused seats are essential for good airflow. A typical competition intake valve seat will consist of a 30-degree top cut 0.100" (2.5 mm) wide, a 45-degree seat .040" (1 mm) wide, and a 70-degree inside cut 0.180" (4.5 mm) wide. An exhaust valve will work well with a 15-degree top cut .060" (1.5 mm) wide, followed by a 45-degree seat 0.060" (1.5 mm) wide, and a 75-degree inside cut 0.100" (2.5 mm) wide. The outside diameter (O.D.) of the valve should coincide with the outside of the 45-degree seat. Flowbench experimentation will frequently uncover a superior shape for any particular head. A three-angle seat will outflow a simple 45-degree seat by up to 25% at lower valve lifts.

7.6 The Valve Seat

The total flow through the engine is ultimately determined by the valve diameters. While well-designed smaller valves will out-perform larger valves on occasion, a good large valve will always outflow a good smaller valve.

Valve size is limited by the diameter of the engine bore. For wedge-shaped combustion chambers, the practical maximum intake valve diameter is 0.52 times the bore diameter. Hemi-heads and pent-roof chambers permit intake valves up to 0.57 times the bore diameter because of the extra space available in the combustion chamber.

Four-valve heads are best, but the engine must operate at very high speed to take advantage of the extra valve area.

The present trend in racing engines is to keep the exhaust system flow to 80% or 90% of the intake system flow. This may be more than is necessary. Tests indicate that power generally does not improve as long as the exhaust flow is greater than 60% of the intake flow. This dictates an exhaust valve diameter 0.77 to 0.80 times as large as the intake valve.

7.0 Flowbench Theory

7.7 Valve Lift and Flow

The airflow through the engine is directly controlled by the valve lift. The farther the valve opens, the greater the flow, at least up to a point. To discuss a wide variety of valve sizes, it is helpful to speak in terms of the ratio of valve lift to valve diameter, or **L/D ratio**. Stock engines usually have a peak lift of ¼ of the valve diameter, or 0.25d. Racing engines open the valves to 0.30d or even 0.35d.

"Figure 7.4: Valve Flow Potential versus Test Pressure" shows how flow varies with lift for a well-designed valve and port. Up to 0.15d, the flow is controlled mostly by the valve and seat area. At higher lifts the flow peaks over and finally is controlled by the maximum capacity of the port. Wedge-chamber intakes have lower flow at full lift because of masking and bends and are port-limited at a 15% lower level.

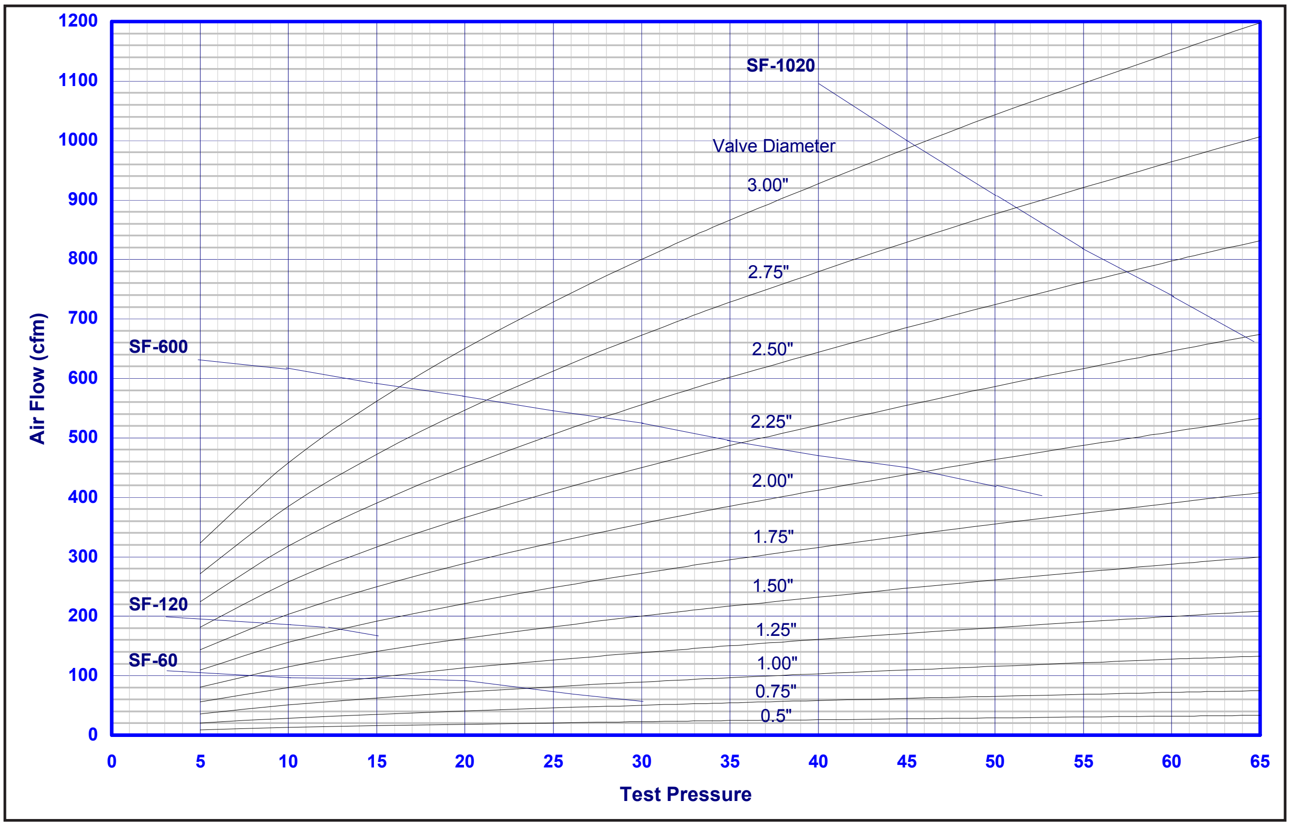


Figure 7.4: Valve Flow Potential versus Test Pressure

The valve flow potential graphs on the following pages can be used as a guide for judging the performance of any valve. To determine the flow rate for a particular valve, multiply the graph **flow/area** by the **valve area** minus the **valve stem area**. The flow rate obtained is not the expected flow rate, but rather the maximum potential flow rate for a particular head at the test pressure.

The maximum potential flow at 25” (60 cm) of water test pressure for some of the popular heads is shown in the comparison chart in "Table 7-4. Maximum Potential Valve Airflow" on page 70.

Table 7-4. Maximum Potential Valve Airflow

	Valve Lift / Valve Diameter					
Intake Valves	**.05d**	**.10d**	**.15d**	**.20d**	**.25d**	**.30d**
	(cfm @ 25" Test Pressure)					
VW 1200, 1.24" d	24.2	48.7	73.0	83.8	89.5	93.1
Norton 850, 1.50" d	40.2	80.5	20.9	161.9	172.6	177.9
Yamaha TX 650, 1.62"d	42.5	85.5	128.4	171.9	183.1	188.1
Chevy Sm Blk, 1.72"d	47.9	96.3	144.7	165.7	177.1	184.5
Chevy Sm Blk, 2.02"d	66.9	134.2	201.7	146.3	231.3	257.2
Chevy Westlake, 2x1.5"d	80.2	160.9	241.9	323.8	345.3	355.7
Ford 302, 2.25"d	83.5	167.6	251.7	288.7	308.3	321.1
Chrysler Hemi, 2.25"d	83.5	167.6	251.7	337.1	359.2	369.0

If the flow reaches a maximum value at a lift of approximately 0.30d, some cams are designed to open the valve farther—even as high as 0.37d—because to open the valve more quickly and longer at lower lifts, it is necessary to overshoot the maximum headflow point. The extra flow is gained on the flanks of the lift pattern, not at the peak.

The headflow figures are for the cylinder head alone with only a radiused inlet guide on the inlet port. When the induction system is installed, the total flow will drop off from 5% to 30%, depending on the flow efficiency of the system. By measuring the flow at each valve lift with and without the induction system, it is possible to accurately measure the flow efficiency. Frequently, the induction system will have even more room for improvement than the cylinder head will.

IMPORTANT
The total flow with the induction system installed must be used in total power calculations.

7.7.1 Valve Flow Potential at Various Test Pressures

Table 7-5. For Hemi-Intake and All Exhaust Valves (English)

	Valve Lift / Valve Diameter							
	.05	.10	.15	.20	.25	.30	.35	.40
Test Pressure	cfm per square inch of valve area							
3”	8.8	16.4	22.7	27.8	31.5	34.0	35.2	35.0
5”	11.3	21.2	29.4	35.9	40.7	43.9	45.4	45.2
7”	13.4	25.0	34.7	42.5	48.2	51.9	53.7	53.5
10”	16.0	29.9	41.5	50.7	57.6	62.1	64.2	63.9
15”	19.6	36.7	50.9	62.2	70.6	76.0	78.6	78.3
20”	19.2	38.6	58.0	77.6	82.7	85.0	88.0	87.3
25”	25.3	47.3	65.7	80.2	91.1	98.2	101.5	101.1
28”	26.7	50.1	69.6	84.9	96.4	103.9	107.4	107.0
36”	30.3	56.8	78.8	96.3	109.3	117.8	121.8	121.3
40”	32.0	59.8	83.1	101.4	115.2	124.2	128.4	127.9
50”	35.8	66.9	92.9	113.4	128.8	138.9	143.5	143.0
60”	39.2	73.3	101.8	124.2	141.1	152.1	157.2	156.6
	Valve area = .785 (D^{2Valve} – D^{2Stem})							

Table 7-6. For Wedge Intake Valves (English)

	Valve Lift / Valve Diameter							
	.05	.10	.15	.20	.25	.30	.35	.40
Test Pressure	cfm per square inch of valve area							
3”	8.8	16.4	22.7	25.7	27.5	28.6	28.6	28.6
5”	11.3	21.2	29.4	33.2	35.5	37.0	37.0	37.0
7”	13.4	25.0	34.7	39.3	42.1	42.8	42.8	42.8
10”	16.0	29.9	41.5	47.0	50.2	52.3	52.3	52.3
15”	19.6	36.7	50.9	57.5	61.5	64.0	64.0	64.0
20”	22.6	42.3	58.7	66.4	71.1	74.0	74.0	74.0
25”	25.3	47.3	65.7	74.2	79.5	82.6	82.6	82.6
28”	26.7	50.1	69.6	78.5	84.0	87.4	87.4	87.4
36”	30.3	55.8	78.8	89.0	95.3	99.2	99.2	99.2
48”	35.0	65.6	91.0	102.7	110.0	114.5	114.5	114.5

Table 7-7. For Wedge Intake Valves (Metric Measurements)

	Valve Lift / Valve Diameter							
	.05	.10	.15	.20	.25	.30	.35	.40
Test Pressure	cfm per square inch of valve area							
8 cm	0.66	1.23	1.70	1.93	2.06	2.14	2.14	2.14
12 cm	0.80	1.51	2.09	2.36	2.53	2.63	2.63	2.63
20 cm	1.04	1.94	2.70	3.05	3.26	3.39	3.39	3.39
25 cm	1.16	2.17	3.01	3.41	3.65	3.79	3.79	3.79
40 cm	1.47	2.75	3.81	4.31	4.62	4.79	4.79	4.79
60 cm	1.80	3.37	4.67	5.28	5.65	5.87	5.87	5.87
70 cm	1.94	3.64	5.04	5.70	6.11	6.34	6.34	6.34
90 cm	2.20	4.12	5.72	6.46	6.92	7.19	7.19	7.19
120 cm	2.54	4.76	6.60	7.46	8.00	8.30	8.30	8.30

Table 7-8. For Hemi-Intake and All Exhaust Valves (Metric Measurements)

	Valve Lift / Valve Diameter							
	.05	.10	.15	.20	.25	.30	.35	.40
Test Pressure	cfm per square inch of valve area							
8 cm	0.66	1.23 1.70	2.08	2.36	2.55	2.64	2.62	28.6
12 cm	0.80	1.51	2.09	2.55	2.90	3.12	3.23	3.21
20 cm	1.04	1.94	2.70	3.29	3.74	4.03	4.17	4.15
25 cm	1.16	2.17	3.01	3.68	4.18	4.51	4.66	4.64
40 cm	1.47	2.75	3.81	4.66	5.29	5.70	5.89	5.87
60 cm	1.80	3.37	4.67	5.71	6.48	6.98	7.22	7.19
70 cm	1.94	3.64	5.04	6.16	6.99	7.54	7.80	7.76
90 cm	2.20	4.12	5.72	6.00	7.93	8.55	8.84	8.80
120 cm	2.54	4.76	6.60	8.07	9.16	9.87	10.21	10.17

From a flow standpoint, a hemi-shaped combustion chamber has a clear advantage over the wedge. Until the valve lift reaches 0.15 valve diameter, there is little difference. At higher lifts, the hemi-valve is usually less shrouded. In most designs, the hemi-port is also straighter because of the valve angle. These two advantages add up to an average flow advantage of 16% at higher lifts, even with equal valve diameters.

Considering that a hemi-combustion chamber also generally permits the intake valve to be 10% greater diameter than a wedge, the success of the hemi-head racing engine is apparent.

7.8 Combustion Chamber

In most engines, it appears the combustion chamber design was dictated by the choice of the valve geometry. Perhaps it should be the other way around. Most combustion chambers basically do not combust as well as they should. Hemi and pent-roof combustion chambers are generally the best; wedge chambers are 5% to 10% worse.

Most gasoline-burning racing engines use a compression ratio between 12 and 14.5 to 1. If the cylinder is completely filled, the expected torque per cubic inch (N-m/liter) of engine displacement should be the same, regardless of engine design. However, it is not the same, and the differences are mostly due to combustion chamber effectiveness.

One way to judge a combustion chamber's performance is to measure the torque output per unit of engine displacement. At the speed of peak torque, a good combustion chamber will develop 1.25 to 1.30 pound-feet of torque per CID (100 to 108 N-m/liter). It may be possible to raise this as high as 1.5 pound-feet per CID (124 N-m/liter), though not without an outstanding combustion chamber design and ram-tuning. Most racing Detroit V8s only reach 1.15 pound-feet per CID (95 N-m/liter). Plenty of room is available for improvement.

A second guideline for judging efficient burning is the required spark advance for maximum power. The more efficient combustion chambers have a higher turbulence and require less spark advance. A turbulent combustion chamber substantially reduces the ignition delay time between when the spark fires and the charge begins to burn rapidly. Ignition timing should be set to develop maximum cylinder pressure at 20 degrees after Top Dead Center (TDC).

For example, a small-block Chevy with a normal combustion chamber shape might require 42 degrees Before Top Dead Center (BTDC) maximum spark advance (35 degrees ignition delay) while a highly turbulent combustion chamber might only require 33 degrees BTDC advance (27 degrees ignition delay). The more turbulent chamber will also burn more rapidly and produce up to 10% greater power from the same initial charge Frequently, trial-and-error methods are the only way to improve combustion chamber performance. In general, strive for high turbulence, and minimize the distance from the spark plug to the farthest part of the combustion chamber.

At times, combustion chamber burning complexities can cause confusion when comparing cylinder heads on an engine. For instance, it is difficult to compare a cylinder head on a Chevy 302 and then a Chevy 330. While the same head will bolt onto both engines, the compression ratio, combustion chamber effectiveness, and rpm range will all change. Even the degree of turbulence will change. These factors can mask differences due to the flow capacity of the heads and confuse even an experienced engine builder.

7.9 Dynamic Flow Effects

Engine volumetric efficiency and power can be increased considerably by taking advantage of the natural dynamic effects that occur during the intake cycle. Both the kinetic energy and the resonant pulses can be harnessed to fill the engine cylinder at volumetric efficiencies up to 130%. Without these dynamic effects, volumetric efficiency is limited to 100% without supercharging.

When the inlet valve closes, a pressure pulse bounces out of the intake tract and then in again toward the valve. By making the intake tract the proper length, the returning pulse can be timed to arrive just after Bottom Dead Center (BDC) of the next intake cycle, forcing in extra air and keeping exhaust gases out of the intake port.

To visualize what occurs, imagine that one end of a steel bar is placed against a hard surface. If the other end is struck with a hammer, a strong pulse (the hammer blow) will travel down the bar to the other end and then back to the hammer end. The pulse will actually cause the bar to jump back toward the hammer. While the bar (or the air in the port) moves very little, a strong pulse transmits through it.

To use this pulse, the intake port must be the correct length. The pulse will help only through a narrow range of rpm. If above or below a certain range, the pulse actually decreases power, so proper synchronization is essential. Several pulses can be used, corresponding to the second, third, and fourth time the pulse arrives at the valve. The second pulse is best because the others are weaker and shorter.

Table 7-9. Inlet Pulsation Chart

Harmonic	Length (inches)	(cm)	Lower rpm	Upper rpm	Pulse Strength*
2nd	132,000/rpm	335,000/rpm	89%	108%	±10%
3rd	97,000/rpm	246,000/rpm	91%	104%	± 7%
4th	74,000/rpm	188,000/rpm	93%	104%	± 4%

* Pulse strength varies with inlet flow and inlet valve opening.

This chart shows the pulses that can be used. To obtain the inlet system length, divide the number shown by the rpm for peak power as determined by the flow measurements (see Chapter "5.0 Operation").

For example, at 8000 rpm for the second harmonic, the formula would be:

Length = 132,000/8,000 = 16.5”

Length = 335,000/8,000 = 41.9 cm

This is the desired length from the intake valve to the air inlet entrance. For engines with a plenum chamber type intake, the length is from the valve to the plenum chamber. The pulse in the example will benefit from 89% up to 108% of 8,000 rpm or from 7,120 rpm up to 8,640 rpm. The greatest benefit will occur at about 3% below 8,000 rpm. Below 7,120 rpm or above 8,640 rpm, the pulse will actually work to decrease engine power.

To gain benefits from the pulsation, it is also necessary that the intake valve be open to a lift of at least 0.02 times the valve diameter by 15 degrees BTDC (Before Top Dead Center). Openings of 20 degrees to 40 degrees BTDC are usually preferable. The intake flow rating must also be 0.3 or greater for significant benefits.

7.0 Flowbench Theory

7.10 Inertia-Supercharge Effect

When the intake valve starts to close, the fast-moving air column tries to keep ramming itself into the cylinder. If the inlet valve is closed at just the right instant, the extra charge will be trapped in the cylinder (called inertia-supercharging). Volumetric efficiencies up to 130% can be obtained. To determine the proper valve timing for maximum inertia-supercharge, it is necessary to determine the inertia supercharge index, Z, and then the valve closing timing can be determined from the Intake Valve Closing Angle graph.

Z, the inertia-supercharge index, depends on the average inlet valve area, so this must be measured.

First determine the inlet flow versus the valve lift for the complete intake system. Next, determine the cam lift profile at the valve versus the degrees of engine rotation.

From these two pieces of information, construct a graph, as shown in "Figure 7.5: Engine Flow Valve Units versus Degrees of Engine Rotation", of engine flow units per unit of valve area versus degrees of engine rotation. This is a plot of the total engine flow considering both the intake system and the cam.

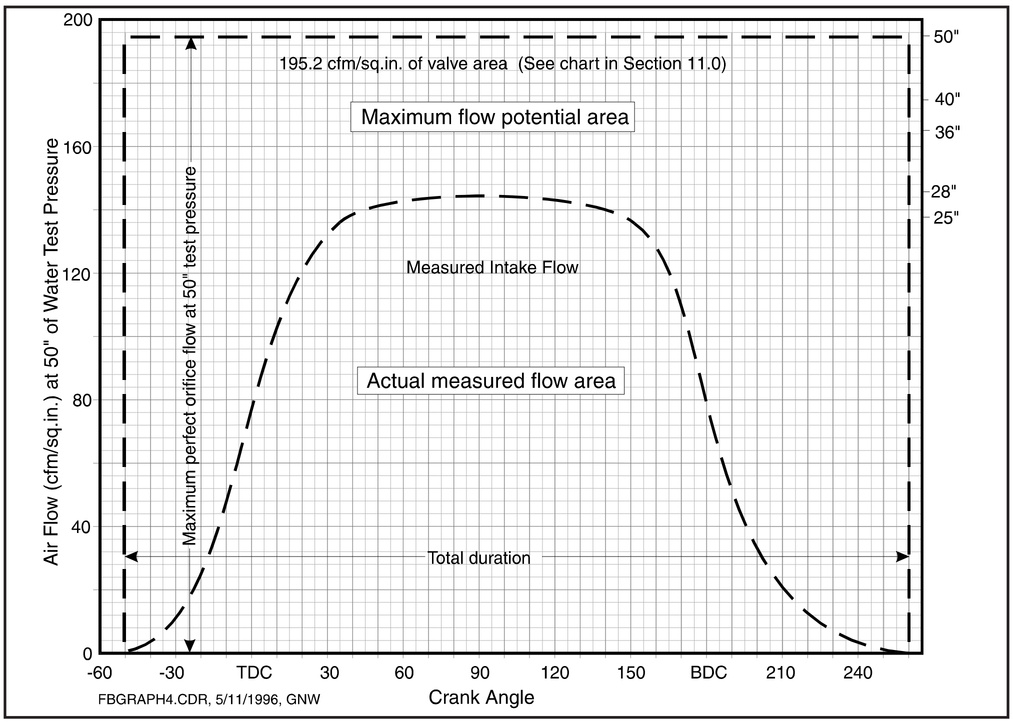


Figure 7.5: Engine Flow Valve Units versus Degrees of Engine Rotation

Count the number of squares under the flow curve and divide this by the total number of squares beneath the maximum valve flow potential line for the test pressure used for the flow test. The number obtained is the intake system flow rating C_v.

$$Cv = \frac{\textbf{AreaUnderFlowCurve}}{\textbf{TotalAreaUnderPotentialFlowLine}}$$

The C_v will generally be between 0.35 and 0.45 for good engines. This is a total rating of the intake system flow for any engine. The higher the C_v, the better the engine.

7.0 Flowbench Theory

The average inlet valve area is the Cv times the intake valve area.

Average Inlet Area = Cv x Valve Area (in2 or cm2)

This data can be used to determine the inertia-supercharge index, Z, from the formula below:

$$Z = \frac{rpm}{126{,}000} \times \sqrt{\frac{\text{CylinderDisplacement (in}^3\text{)} \times \text{InletLength (in)}}{\text{AverageInletArea (in}^2\text{)}}}$$

$$Z = \frac{rpm}{320{,}000} \times \sqrt{\frac{\text{CylinderDisplacement (cm}^3\text{)} \times \text{InletLength (cm)}}{\text{AverageInletArea (cm}^2\text{)}}}$$

Z is usually between 0.9 and 1.2 and is also a measure of the strength of the inertia-supercharge to obtain. When Z is determined, use the graph to obtain the correct intake valve closing angle where the valve should be closed down to a lift of .01 x valve diameter.

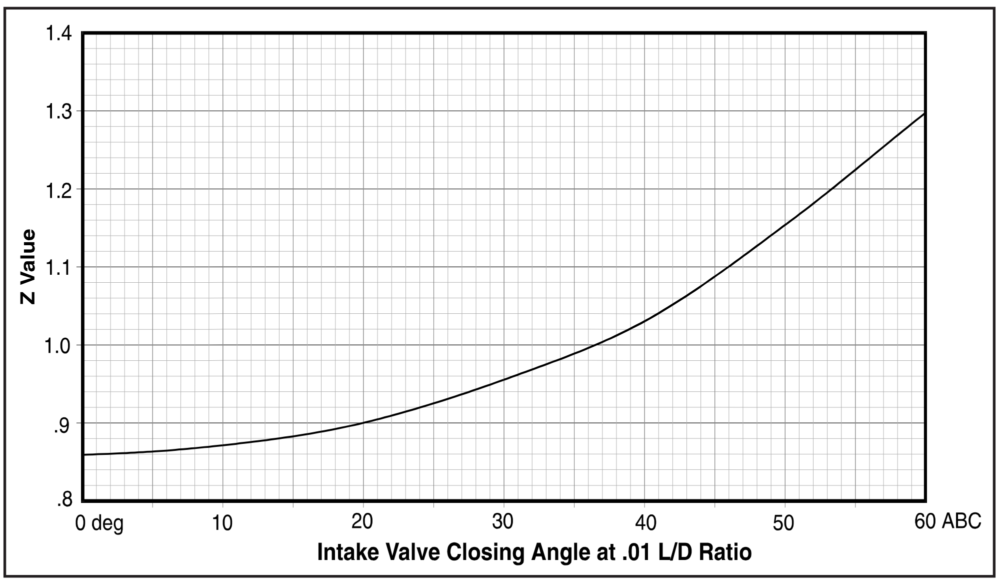


Figure 7.6: Intake Valve Closing Angle at .01 L/D Ratio

8.0 Flowbench Applications and Techniques

8.1 Test Pressures and Comparing Flow Numbers

The necessity of flow number comparison is something anyone involved in flow testing must endure. Even if the number comparison is made on the same components and flowbench, it is important to know how to compare the numbers so the time and effort is worthwhile. The comparison process is necessary to evaluate published numbers vs. your own developed flow numbers. The first principle you learn in flow testing is that you must ask (or qualify) at what test pressure the flow numbers were recorded.

"Table 8-1. Flowbench Test Pressure Conversion Chart" is based on the square root of the pressure ratio method. If you have flow numbers at a known test pressure and want to compare those numbers at a different test pressure, it is easy to do. The formula is:

$$\mathbf{FlowAtFirstTestPressure} \times \sqrt{\frac{\mathbf{SecondTestPressure}}{\mathbf{FirstTestPressure}}} = \mathbf{FlowAtSecondTestPressure}$$

As an example, if you have flow numbers at 10"H_2O test pressure and would like to know what the flow should be at 25"H_2O test pressure, the formula is:

$$\sqrt{(25/10)} = 1.58$$

So you would multiply the flow numbers taken at 10”H_2O test pressure by 1.58 to see what the flow would be at 25"H_2O.

Table 8-1. Flowbench Test Pressure Conversion Chart

	Want Flow At:												
Have Flow At	**3**	**5**	**7**	**10**	**12**	**15**	**20**	**25**	**28**	**30**	**35**	**40**	**45**
3	1.000	1.290	1.530	1.820	2.000	2.240	2.580	2.890	3.050	3.160	3.420	3.650	3.870
5	0.774	1.000	1.180	1.410	1.550	1.730	2.000	2.240	2.370	2.450	2.650	2.830	3.000
7	0.655	0.845	1.000	1.120	1.310	1.460	1.690	1.890	2.000	2.070	2.240	2.390	2.540
10	0.548	0.707	0.387	1.000	1.090	1.220	1.410	1.580	1.670	1.730	1.870	2.000	2.120
12	0.500	0.645	0.764	0.913	1.000	1.120	1.290	1.440	1.530	1.580	1.710	1.830	1.940
15	0.447	0.577	0.683	0.816	0.894	1.000	1.150	1.290	1.370	1.410	1.530	1.630	1.730
20	0.387	0.500	0.592	0.707	0.774	0.866	1.000	1.120	1.180	1.220	1.320	1.410	1.500
25	0.346	0.447	0.529	0.632	0.693	0.775	0.894	1.000	1.060	1.100	1.180	1.260	1.340
28	0.327	0.422	0.500	0.598	0.654	0.721	0.845	0.945	1.000	1.040	1.120	1.200	1.270
30	0.316	0.408	0.483	0.577	0.632	0.707	0.816	0.913	0.966	1.000	1.080	1.150	1.220
35	0.293	0.378	0.447	0.535	0.586	0.655	0.756	0.845	0.894	0.926	1.000	1.070	1.130
40	0.274	0.354	0.418	0.500	0.548	0.612	0.707	0.791	0.837	0.866	0.935	1.000	1.060
45	0.258	0.333	0.394	0.471	0.516	0.577	0.667	0.745	0.789	0.816	0.882	0.943	1.000
50	0.245	0.316	0.374	0.424	0.490	0.547	0.633	0.707	0.749	0.774	0.837	0.895	0.949
60	0.224	0.289	0.341	0.387	0.447	0.499	0.578	0.645	0.684	0.707	0.764	0.817	0.866

8.0 Flowbench Applications and Techniques

Example 1:

If flow is 65 cfm at a test pressure of 5”, what would the flow be at 15”?

$$\textbf{CFM} = \textbf{65} \times \sqrt{\frac{\textbf{15}}{\textbf{5}}} = \textbf{65} \times \textbf{1.73} = \textbf{112.5}$$

Example 2:

If flow is 42 l/s at a test pressure of 12 cm, what would flow be at 40 cm?

$$\textbf{CFM} = \textbf{65} \times \sqrt{\frac{\textbf{15}}{\textbf{5}}} = \textbf{65} \times \textbf{1.73} = \textbf{112.5}$$

Flow at any test pressure will vary as the square root of the ratios of the two test pressures.

Example 3:

If flow is 122 at a test pressure of 7, what will the flow be at a test pressure of 28?

$$\textbf{CFM} = \textbf{65} \times \sqrt{\frac{\textbf{15}}{\textbf{5}}} = \textbf{65} \times \textbf{1.73} = \textbf{112.5}$$

8.2 Useful Flowbench Tools

The skillful use of tools makes the job of testing airflow more fun than makeshift approaches and is very useful:

- **Head Adapter:** Cylinder heads are mounted onto the SuperFlow flowbench with an adapter. The adapter usually consists of a tube with the same bore as the engine and a flange on each end. The lower flange is bolted to the flow tester, and the upper flange is bolted or clamped to the test cylinder head. The flanges must be flat or gasketed to make an airtight seal. Head adapters that have sliding plates are available to facilitate testing multiple cylinders without having to remove the entire apparatus.
- **Valve Opener:** When testing cylinder heads, a means must be provided to hold the valve at very precise lifts. Generally, these devices consists of a clamp, some sort of movable bar or stud, and a dial indicator. The bar or stud usually has a threaded rod with a lock nut to hold the valve in position.

  Some products on the market are now computer controlled, making the testing process much faster and more precise.
- **Magic Wand:** Provides an indication of activity and direction of flow inside a port or device under test. The magic wand is made from a 12” long welding rod with a 1/16" diameter. The welding rod has a small round ball on the end (from placing the rod in a molten pool of metal), and a piece of dacron or nylon type kite string is glued to it to form a little flag about 3/8" long. This is a good flow visualization indicator.
- **Pitot Tube:** Provides a way to probe the port to supply local velocity numbers. Can be used with SuperFlow’s FlowCom, pressure manometer, or special port software to plot areas of activity in the airstream in a port. It is difficult to use in very small ports and requires one type for exhaust use and a different one for intake use.

8.0 Flowbench Applications and Techniques

- **Flow Ball:** Provides a method to probe a port and verify if flow is attached or separated at some point in the port. Flow balls are made by tack welding various diameters of ball bearings to a 12” long welding rod with a 1/16" diameter. Flow balls typically start with 1/8" diameter and go to 1/2" diameter in 1/16" increments. These tools are an easy way to find problem areas in the port without great difficulty and are very effective in evaluating the short-turn radius in a port or where a wall has a directional change.
- **Tell-tale Probe:** This probe helps visualize the airflow. A probe consists of a small diameter rod, such as a brazing or welding rod, with a groove ground near one end. A piece of lightweight string is tied in the groove with a loose knot so it may rotate but not slide out of the groove. Adding a small drop of glue to the knot helps prevent it from untying during use. Trim the tail of the string to approximately ½ inch [13 mm] in length. A correctly constructed tell-tale probe rotates in the direction of the airflow and moves freely on the probe. Test the probe by blowing on it. It should immediately align to the direction of flow.
- **Port Molding Rubber:** Provides an easy way to look at a port. The mold is made of silicone-based material (a two-part process) that is poured into the port (with valve in place); after it sets, it can be removed in one piece. The mold can be sliced and the cross-sectional profile drawn on graph paper to help measure the area at different locations in the port.
- **Swirl Meter:** The swirl meter mounts between the bore adapter and the flowbench and records the gross axial or circular motion of the airflow into the intake of a cylinder head. Sometimes a cylinder head with good motion or swirl performs better because it will burn the fuel/air mixture faster. A swirl meter can help determine this motion.
- **Bore Simulation Adapter:** All flow testing of cylinder heads should use an adapter that simulates the bore size within 1/16” of the diameter used on the engine. The length of the simulated bore should be at least equal to the diameter or more.
- **Graph Paper:** An easy way to measure the cross-sectional area in a port. The paper cut-outs are trimmed to fit different places in the port, and the squares can be counted, providing an accurate way of measuring the areas.
- **Poster Board:** An easy way to make patterns to help the developer reproduce the same port shape and size. The poster board can then be used to trace patterns in aluminum or plastic that provides benchmarks to use in duplicating an established shape in other ports and cylinder heads of the same type.
- **Radius Inlet Guide:** Provides a smooth approach to the port or device being tested and is intended to decrease the “edge effect” at the port flange. The radius used should be as large as possible and have at least ½" radius. The thickness of the inlet guide and the size outside he port cross-section should be at least 50% of the height of the port so all directions have a smooth approach. It is not uncommon for the inlet guide to improve the flow from 6% to 10% over no guide in use.
- **Exhaust Pipe:** All testing of the exhaust side of the cylinder head should use a short section of exhaust pipe that is at least the diameter of the port. The appropriate length is about 10" to 12" long.
- **Bore Simulation Adapter:** All flow testing of cylinder heads should use an adapter that simulates the bore size within 1/16" of the diameter used on the engine. The length of the simulated bore should be at least equal to the diameter or more.

- **Wet Flow Adapters:** Provides another reference of flow visualization that is valuable in evaluating what is happening in the combustion chamber and helps sort out problems in that area. It is best when at an air/liquid ratio that represents the normal air/fuel ratio an engine uses. This process has helped solve problems that otherwise would go unnoticed.
- **Calculator:** Ever present when the flow tester is on the phone comparing numbers with another tester, the calculator provides an instant indication of hype vs. truth because known numbers are compared to claims.

8.3 Predicting Horsepower based on Airflow Numbers

The performance coefficient SuperFlow developed is based on very accurate empirical data and even 30+ years after its introduction to the marketplace, it is still a good indicator of power capability of an engine based on its airflow. Today's engines are more efficient because of airflow improvements that were generated by thousands of people searching for more power.

The prediction of horsepower based on airflow numbers can be applied if the test pressure is known. The results are a good estimate of the engine's capacity to make power if everything in the system is optimized to take advantage of the airflow available. An accurate estimate of the power capacity of the engine is dependent upon having accurate flow numbers for the complete airflow system including the cylinder head, manifold, carburetor or fuel injection system.

The power coefficient varies with the test pressure. The following can be used for a quick evaluation of airflow numbers at different test pressures:

The equation: HP/cyl = C_{power} x Test Flow

Where C_{power} = Coefficient of power, Test Flow = cfm flow at the same test pressure that the C_{power} is applied

C_{power} for 10"H_2O = .43

15"H_2O = .35

25"H_2O = .27

28"H_2O = .26

These numbers assume the engine is using gasoline for fuel.

Example 1:

If you have system airflow numbers recorded at 25"H_2O and the flow was 200 cfm, the calculation would be **HP/cyl = .27 x 200 = 54HP/cyl**.

If you were working on an eight-cylinder engine, then 8 x 54 = 432HP capacity. This assumes that each port flows the same number.

More accurate results can be applied if the same calculation is made for each port if the airflow is not the same.

8.4 Predicting Peak Power rpm based on Airflow Numbers

Predicting the rpm at which peak power will occur (based on airflow) is an additional useful way to evaluate airflow numbers and an easy way to see the effects of changing engine displacement.

The equation: RPM at peak power = [(C_{rpm}) /(displacement /cyl)) x cfm]

Where C_{rpm} = Coefficient for peak power rpm calculation, displacement / cyl = displacement per cylinder in cubic inches, cfm = cubic feet per minute from flowbench data taken at a given test pressure.

C_{rpm} for 10”H_2O = 2000

15”H_2O = 1633

25”H_2O = 1265

28”H_2O = 1196

These numbers assume the engine is using gasoline for fuel.

Example 1:

Using the same numbers that were applied in the previous example for power/cylinder above (200 cfm at 25”H_2O and the engine is an eight-cylinder engine with a displacement of 355 cubic inches), **355/8 = 44.375** cubic inches per cylinder. Applying the equation and solving for rpm at peak power, where **RPM_{pp} = (1265 / 44.375) x 200 = 5701 rpm**.

Just for fun, what would happen to this number if the engine were 455 cubic inches? Now the engine displacement divided by the number of cylinders yields an entirely different number. So, **455/8 = 56.875**. Applying the equation for rpm at peak power, **RPM_{pp} = (1265 / 56.875) x 200 = 4448 rpm**.

8.0 Flowbench Applications and Techniques

8.5 Testing Cylinder Heads

Test Preliminaries

Cylinder heads are mounted onto the SuperFlow flowbench by a cylinder adapter. The adapter usually consists of a tube 4" (101 mm) long with the same bore as the engine and a flange on each end. The lower flange is bolted to the flow tester and the upper flange is bolted or clamped to the test cylinder head. The flanges must be flat or gasketed to make an airtight seal. The adapter tube may be 0.06" (1.5 mm) larger or smaller than the actual engine cylinder. In some cases, it is convenient to make the upper flange of the adapter about 20% wider than the test cylinder head so the head will be supported when it is offset for testing the end cylinders.

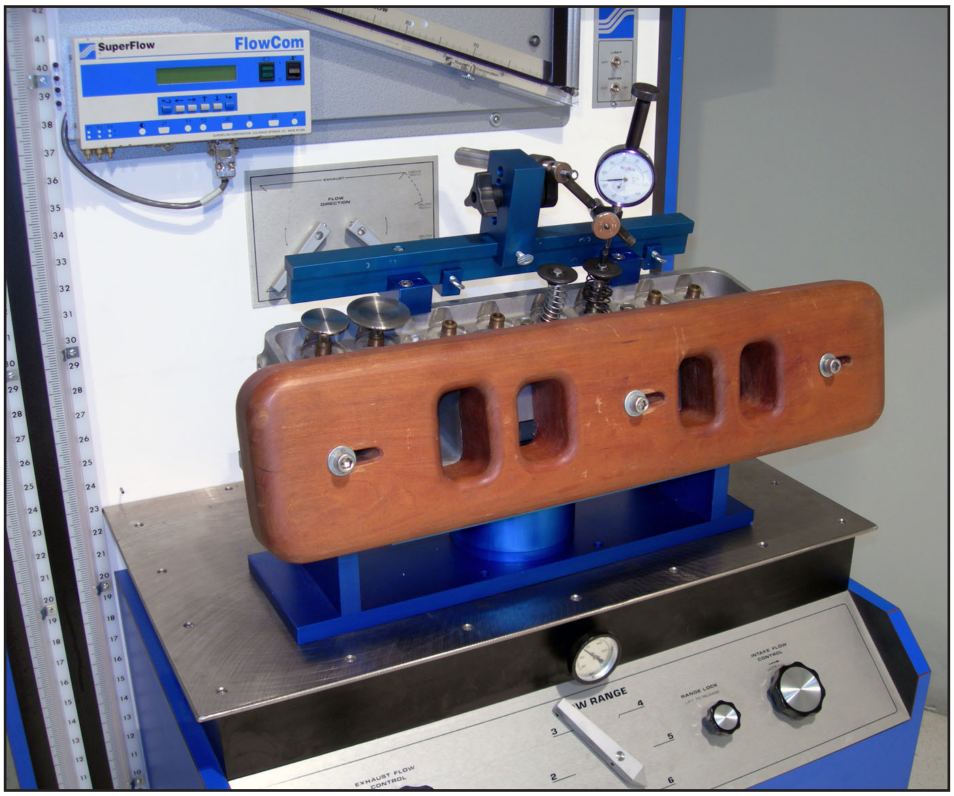


Figure 8.1: Cylinder Head on Adapter

A device must be attached to the cylinder head to open the valves to the various test positions. The usual method is to attach a threaded mount to a rocker arm stud so the end of a bolt contacts the end of the valve stem. As the bolt is rotated, it pushes open the valve. A 0 to 1" x 0.001 (20 mm x 0.1) dial indicator may be mounted to the same fixture with its tip contacting the valve spring retainer to measure the amount of valve opening. The standard valve springs should be replaced with light springs for testing.

8.0 Flowbench Applications and Techniques

On the intake side of the cylinder head, SuperFlow strongly recommends installing a radiused inlet entrance guide to lead the air straight into the head. The guide should be about one port width in thickness and be generously radiused on the inside all the way to the head. The intake manifold can also be used. The exhaust flow may exit directly from the head.

Operators may record all test data on the SuperFlow test data sheets.

Contact SuperFlow Customer Service if you need forms to use as templates or examples. Flow software can automatically plot the data. Additional factors and relationships are discussed in Chapter "7.0 Flowbench Theory".

Figure 8.2: Valve Opener

Before beginning a test, record the head description, and measure the valve stem and valve diameter. The **net valve area** is the **valve area** minus the **stem area**.

Net valve area = 0.785 (valve Diameter^2 – stem Diameter^2)

Where:

- Surface area = πR^2
- The constant **0.785** = $\pi/4$

All engine valve tests should be performed at the same ratio of valve lift to valve diameter, or **L/D ratio**. Then the flow efficiencies of any valves can be compared, regardless of size. Multiply the **valve diameter** by each of the seven **L/D ratios** (0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35) to obtain the **valve lift** test points. Fill these in on the data sheet.

Use the flow ranges listed in Table 8-2 to ensure your flowbench will not run out of capacity as you improve the flow of your test head.

Table 8-2. Valve Diameter vs. Flow Range

Valve Diameter	Suggested Flow Range for 25" (63.5 cm) Test Pressure
1.00” (25 mm)	Range 3–100 cfm (47 lps)
1.50” (38 mm)	Range 4–150 cfm (71 lps)
1.50” (38 mm)	Range 5–200 cfm (94 lps)
1.75” (45 mm)	Range 6–300 cfm (142 lps)
2.00” (51 mm)	Range 7–400 cfm (189 lps)
2.25” (57 mm)	Range 8–500 cfm (236 lps)
2.50” (63 mm)	Range 8–500 cfm (236 lps)
2.75” (70 mm)	Range 9–700 cfm (330 lps)

8.0 Flowbench Applications and Techniques

Flow Testing

Assume the test pressure is 25.0” (60.0 cm) for this example.

1. Remove the test orifice plate from the flowbench and install the test head, cylinder adapter, and valve opener for the actual flow tests.
2. Set the **dial indicator** to read zero with the valve closed. Install either the intake manifold or an air inlet guide on the intake port.
3. FlowCom users: press the **ENTER** button (↵) and set the desired **test pressure**.
4. Turn on the flowbench motors.
   - Without motor controller: open the flow control valve until the desired test pressure is reached.
   - With motor controller: observe whether the test pressure displays the test pressure you intend to use.
5. Perform a **leakage** test with the valves closed.
   - On range 1, **leakage** is usually from 0.5 to 2 cfm (0.50 to 1.0 l/s).
   - If no leakage occurs, the corrected test flow may read zero. The leakage will not affect the test as long as the leakage is entered into the data or into the FlowCom.
6. Turn the motors off. Enter the leakage value onto the data sheet or into FlowCom according to the leakage procedure.
7. Open the valve in the test head to a lift of 0.20 x valve diameter (l/d = 0. 20).
8. Change the flow range to desired range on flowbench and on FlowCom.

TIP: When the proper range for this head and valve lift is determined, make note of it for future reference. Always use the same combination on follow-up tests for accurate comparisons.

9. Turn on the flowbench motor switch and adjust the test pressure.
   - The green push-button switch on the FlowCom panel turns the motors on. FlowCom automatically adjusts the motor power output for the entered test pressure.
10. Record the flow reading on FlowCom.
11. Turn off the motor.
12. Record the readings on the data sheet.
    - **FlowCom:** Record the flow reading as shown on the display. FlowCom automatically corrects for leakage and the temperature difference.
13. Open the valve to the next valve lift and repeat the above steps. (Each valve lift may require a different flow range). Continue this procedure until you reach the maximum valve lift test point.

NOTE: To test the exhaust port, turn the flow mode switch to exhaust and close the intake flow control valve. Move the valve opener and dial indicator to the exhaust valve and repeat the above procedures.

This completes the test.

8.0 Flowbench Applications and Techniques

Analyzing the Test Data

For simple analysis of the test results, it is only necessary to calculate the **Test Flow**. First calculate the **Raw Test Flow** by multiplying the F**low Scale Reading** times the **Corrected Flow range**. Then subtract the **Leakage**. The result is the **Test Flow**. This flow can be compared to other tests of the same head with the same setup without further calculations. No atmospheric corrections are required. Atmospheric differences cancel out automatically.

1. To obtain the valve efficiency, it is necessary to calculate the flow in cfm/square inch (lps/sq.cm) of valve area and then compare that flow to the best yet achieved.
2. Divide **Corrected Test Flow** by the **Effective Valve Area** to obtain **Test Flow**.
3. Fill in the **Potential Flow** from the chart in section "7.7.1 Valve Flow Potential at Various Test Pressures" on page 71 at the test pressure for your test.
4. Divide **Test Flow** (CFM/in^2) by **Potential Flow** and multiply by **100%** to obtain the **% Potential Flow**. The **% Potential Flow** can be used as an indicator of the remaining improvement possible.
5. To determine the valve C_d (coefficient of discharge) Test Flow/unit area by the Maximum Potential Flow/Unit Area for that test pressure from section "7.7.1 Valve Flow Potential at Various Test Pressures" on page 71.

Example 1:

The Maximum Potential Orifice Flow/ Unit Area at 25” H_20 is 138 cfm/sq.in.

If test flow is measured as 132.3 cfm/sq.in., the C_d is:

$$C_d = \frac{TestFlow}{PotentialOrificeFlow}$$

or

$$C_d = \frac{132.3}{138} = 0.958$$

The flow results can also be plotted on graphs. Contact SuperFlow Customer Service if you need forms to use as templates or examples. Flow software can automatically plot the data.

8.0 Flowbench Applications and Techniques

8.6 Adapting the SuperFlow Flowbench to Two-stroke Engines

The SuperFlow flowbenches can adapt to two-stroke engine cylinder development. For two-stroke engine cylinder testing, you must measure both the flow quantity and the flow direction.

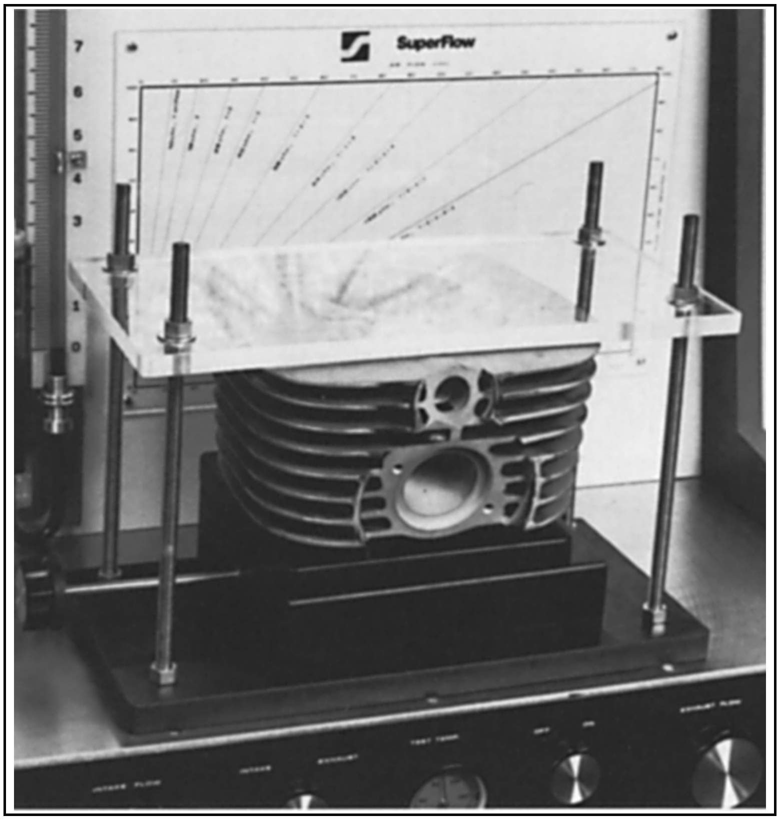


Figure 8.9: Two-Stroke Cylinder Mount

1. To perform a flow test, it is first necessary to mount the two-stroke cylinder onto the flowbench. "Figure 8.9: Two-Stroke Cylinder Mount" shows a typical two-stroke cylinder mounting system with a Yamaha cylinder mounted onto an SF-110 flowbench.
    - The cylinder is mounted with a standard piston in place inside the cylinder. The piston should have only one very light piston ring or no piston rings.
    - A lever mechanism is attached to the piston to allow the piston to be positioned up and down in the cylinder during testing.
    - The piston should be adjustable at all positions from fully open port to fully closed port.
    - The mechanism must be strong enough to resist the flowbench air pressure without movement.
2. On top of the cylinder, fit a Plexiglas® cover to allow viewing into the cylinder from the top side. SuperFlow also recommends installing a light in the Plexiglas cover to illuminate the interior of the cylinder. A small flashlight bulb works well.

3. To perform a test, measure flow by blowing air into the base of the cylinder and up through the ports at increments of the piston opening. It may be desirable to mount a dial indicator on the cylinder head Plexiglas cover to measure the exact position of the piston. Use this series of tests to evaluate the quantity of the flow that can pass through the cylinder.
4. The most important test is determining the direction of the flow.
   - To help visualize the airflow, it is necessary to build an airflow tell-tale probe which consists of a small diameter rod, such as a brazing or welding rod, with a groove ground near the tip.
   - In the groove, tie a piece of lightweight string with a loose knot so it may rotate on the groove but will not slide out of the groove. Adding a small drop of glue to the knot helps prevent it from untying during use.

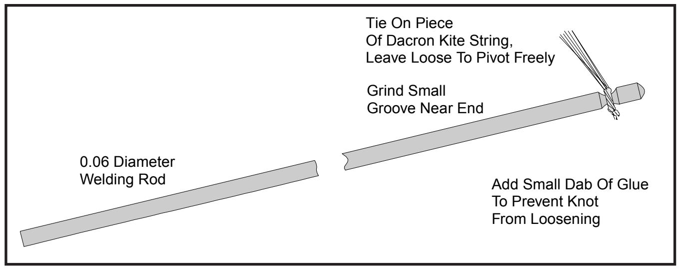


Figure 8.10: Airflow Tell-tale Probe

   - Trim the tail of the string to approximately .25 inches (6 millimeters) in length.
     - A correctly constructed tell-tale probe rotates in the direction of the airflow and moves freely on the probe.
     - The tail should not be tied securely to the probe but should rotate in the groove. Test the probe by setting the tell-tale at right angles to the direction of your breath, and then blow on it. It should immediately align to the direction of flow.
5. After successfully constructing a tell-tale probe, insert the probe through the exhaust port of the engine, or if desired, through a port in the plastic cylinder head cover, and sample the direction of the airflow at all points in the cylinder.
   - It is generally agreed that for a good cylinder configuration, the air should flow up the side of the cylinder opposite the exhaust port, across the top of the head, and down the exhaust port side to exit from the exhaust port.
   - No short-circuiting should occur from the intake port across the head of the piston to the exhaust port.
   - Also, no dead spots of airflow should occur in the cylinder. The goal is to achieve this at all port opening positions.
6. For the initial testing program, use testing cylinders that are known to be good and known to be bad. By observing the differences between these, you can ascertain the features which make one set of cylinders perform better than another. No cylinder is likely to meet all of the goals.

NOTE: Two-stroke cylinder development is still largely theory, and many different techniques have been used to produce similar final results. No single correct way or best theory exists at this time.

SuperFlow builds engine testing equipment but does not normally perform engine cylinder testing. SuperFlow technicians not only answer questions involving flowbench use, but also have a wide range of knowledge about the exact techniques that produce good results on a given cylinder.

8.7 Conclusion

Many applications involve a specific need to know the airflow of engine components and how the engine uses air. Applying simple equations can compare the airflow of components. Many relationships can be enhanced if the airflow is known including valve timing (camshaft selection), inertia tuning factors of intake, power per cylinder capacity, and the rpm at which peak power will occur.

You can learn valuable information by studying airflow through engine components and the engine itself. Because the engine is a self-driven air pump, many of the characteristics of the engine are set by its capacity to flow air.

More information is available from SuperFlow. Visit www.superflow.com.

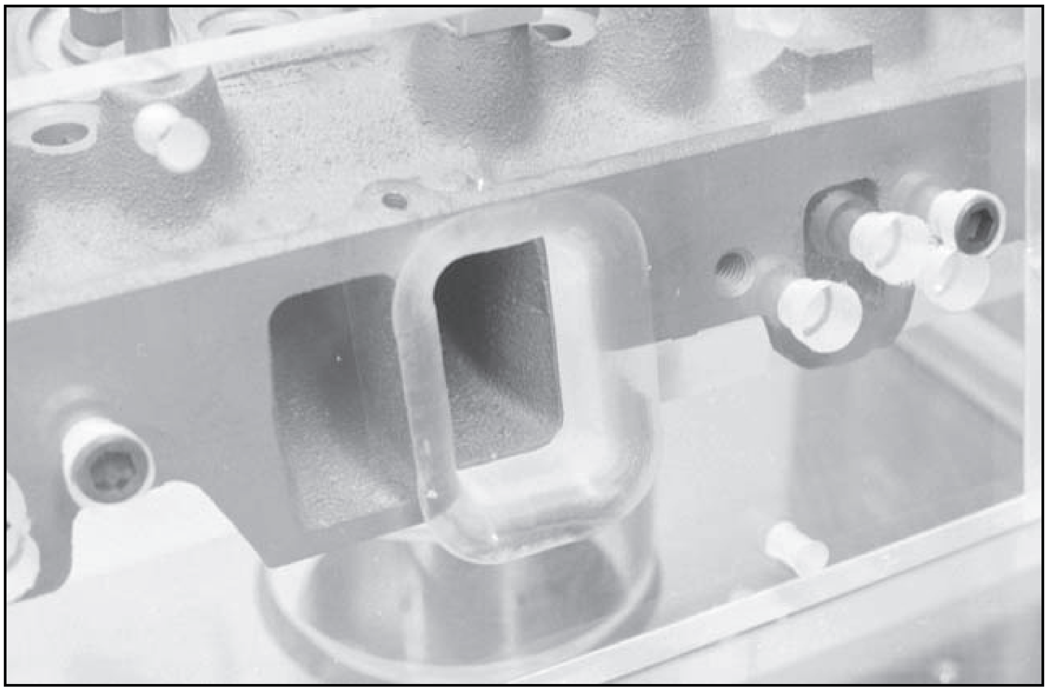


Figure 8.11: Cylinder head with radius inlet guide in place on a bore adapter affixed to a flowbench for airflow study and evaluations. What goes on here begins to set the character of the engine. Note that the radius inlet guide has a large radius and is thick as well, providing a smooth entry for air.

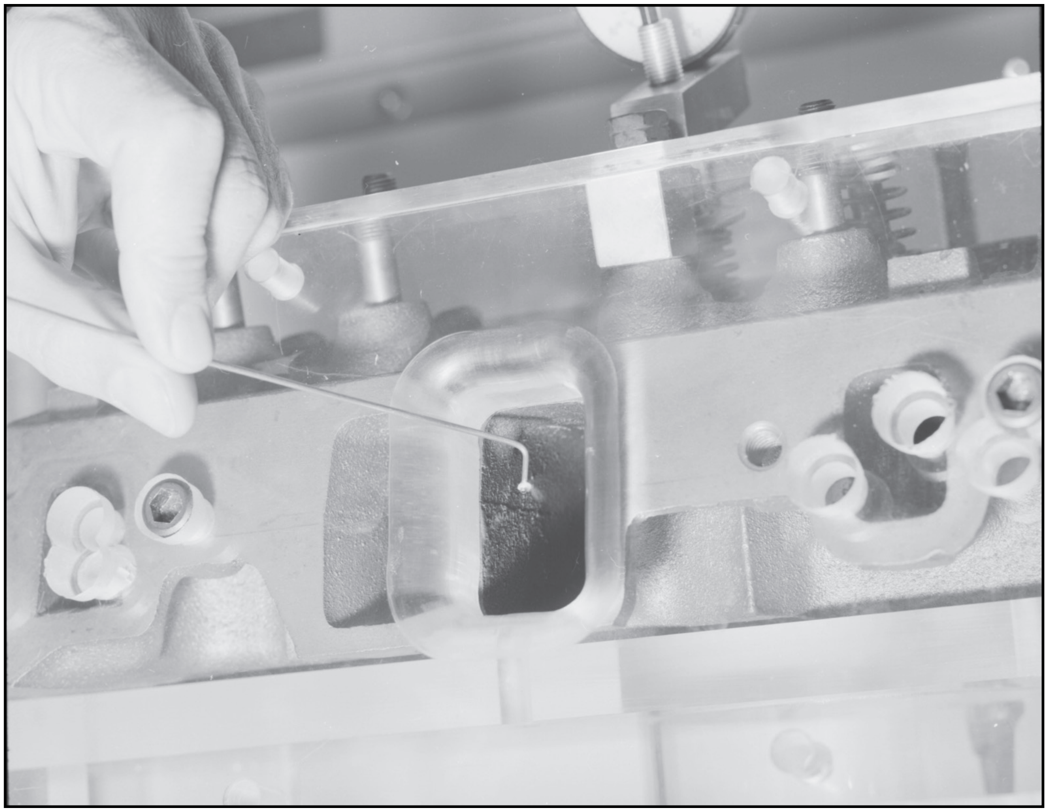


Figure 8.12: Using a “magic wand” allows the flowbench operator to easily visualize the direction and activity in the port. This wand is bent, but wands can also be straight.

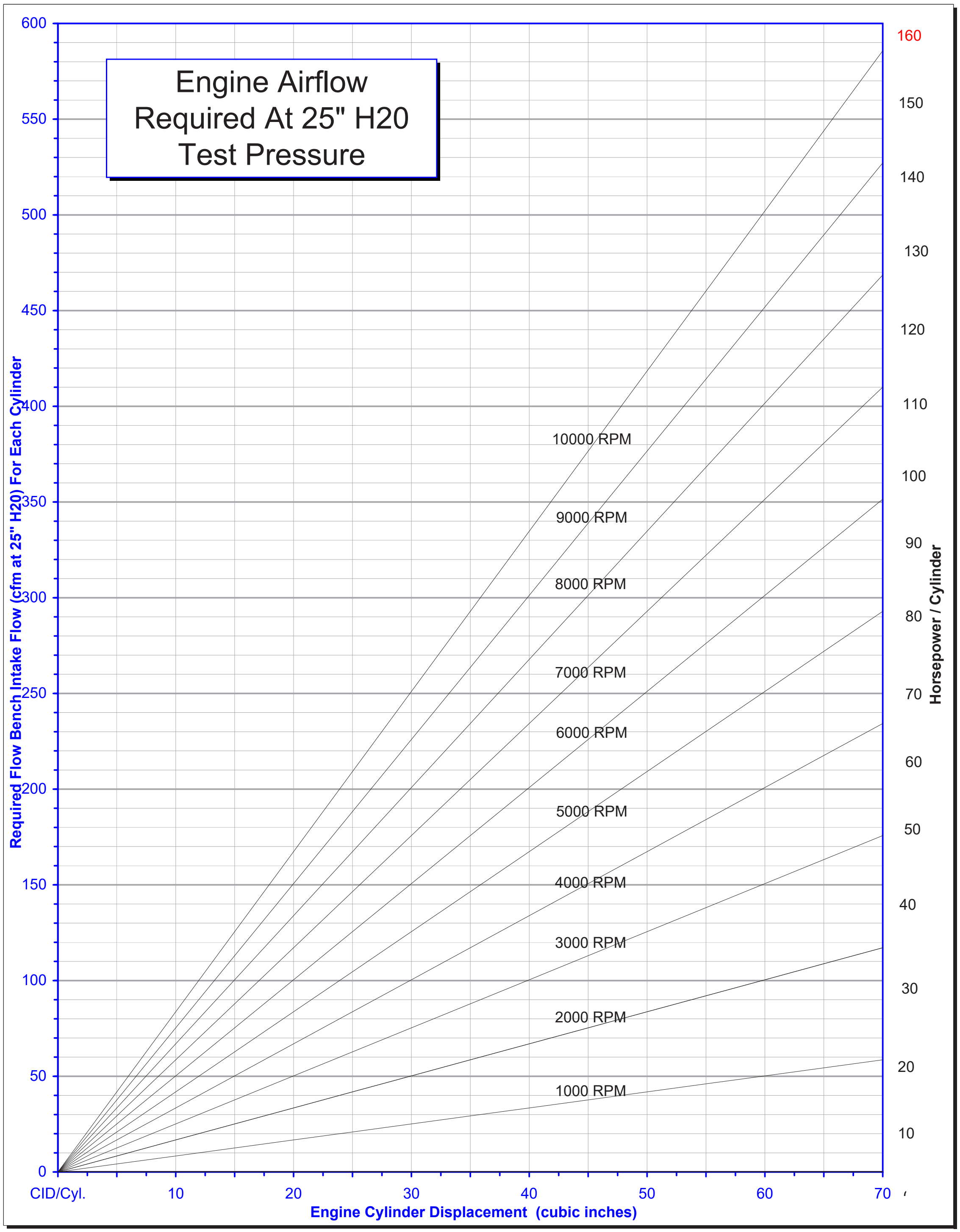


Figure 8.13: Airflow, displacement, engine rpm and horsepower per cylinder can be read directly from this chart. The airflow numbers relate to flow testing at 25"H_2O.

9.0 Appendix

9.1 Unit Conversions

Flow Rate vs. Test Pressure Conversions

Table 9-1. Maximum Potential Orifice Flow Rate versus Test Pressure (English)

Test Pressure (H_2O)	Peak Velocity (ft./sec)	Flow/Unit Area* (cfm/sq. in)
1”	66.2	27.6
3”	114.7	47.8
5”	148.0	61.7
7”	175.1	72.9
10”	209.3	87.1
12”	229.3	95.6
15”	256.4	106.9
20”	296.0	123.4
25”	331.0	138.0
28”	350.3	146.0
30”	362.6	151.1
35”	391.6	163.3
40”	418.7	174.6
45”	444.1	185.1
48”	458.6	191.2
50”	468.1	195.2
60”	512.8	213.8
65”	533.7	222.5

* Through a perfectly streamlined orifice (coefficient of velocity and discharge = 1).

9.0 Appendix

Table 9-2. Maximum Potential Orifice Flow Rate versus Test Pressure (Metric)

Test Pressure (cm H_2O)	Peak Velocity (m/s)	Flow/Unit Area* (lps/sq. cm)
2	17.9	1.79
8	35.8	3.58
12	43.9	4.39
20	56.7	5.67
25	63.3	6.33
40	80.1	8.01
60	98.1	9.81
70	106.0	10.60
90	120.2	12.02
100	126.7	12.67
120	138.8	13.88
130	144.5	14.45
165	162.7	16.27

* Through a perfectly streamlined orifice (coefficient of velocity and discharge = 1).

Table 9-3. Pressure Conversion Units

Have	Multiply By	To Get
Inches of water (inH_2O)	0.03610	Pounds per square inch
Inches of water (inH_2O)	0.0736	Inches of Mercury (inHg)
Inches of water (inH_2O)	2.54	Centimeters of water (cmH_2O)
Inches of water (inH_2O)	0.2488	Kilo pascals per square cm (kPa)
Centimeters of water (cmH_2O)	0.3937	Inches of water (inH_2O)
Centimeters of water (cmH_2O)	0.0142	Pounds per square inch (psi)
Centimeters of water (cmH_2O)	0.0978	Kilo pascals per square cm (kPa)
Centimeters of water (cmH_2O)	0.000978	Bar
Pounds per square inch (psi)	27.70	Inches of water (inH_2O)
Inches of mercury (inHg)	0.4897	Pounds per square inch (psi)
Inches of mercury (inHg)	13.57	Inches of water (inH_2O)
Kilo pascals per square cm (kPa)	4.019	Inches of water (inH_2O)
Bar	1022	Centimeters of water (cmH_2O)
Bar	14.50	Pounds per square inch (psi)

9.0 Appendix

Flow Conversions

Table 9-4. Flow Conversion Units

Have	Multiply By	To Get
Cubic feet per second (ft3/sec)	0.0283	Cubic meters per second (m3/sec)
Cubic feet per second (ft3/sec)	28.32	Liters per second (l/s)
Cubic feet per minute (ft3/min)	0.472	Liters per second (l/s)
Cubic feet per minute (ft3/min)	0.0283	Cubic meters per minute (m3/min)
Cubic feet per minute (ft3/min)	1.700	Cubic meters per hour (m3/hr)
Cubic meters per second (m3/sec)	2120	Cubic feet per minute (ft3/min)
Cubic meters per minute (m3/min)	35.3	Cubic feet per minute (ft3/min)
Cubic meters per hour (m3/hr)	0.589	Cubic feet per minute (ft3/min)
Liters per second (l/s)	2.12	Cubic feet per minute (ft3/min)
Liters per second (l/s)	3.60	Cubic meters per hour (m3/hr)

Length Conversions

Table 9-5. Length Conversion Units

Have	Multiply By	To Get
Inches	25.4	Millimeters (mm)
Inches	2.54	Centimeters (cm)
Centimeters (cm)	0.3937	Inches
Millimeters (mm)	0.3937	Inches
Millimeters (mm)	0.10	Centimeters (cm)

Speed Conversions

Table 9-6. Speed Conversion Units

Have	Multiply By	To Get
Feet per second (ft/sec)	0.3049	Meters per second (m/s)
Feet per minute (ft/min)	0.00508	Meters per second (m/s)
Meters per second (m/s)	3.28	Feet per second (ft/sec)
Meters per second (m/s)	0.0547	Feet per minute (ft/min)

9.0 Appendix

Power Conversions

Table 9-7. Power Conversion Units

Have	Multiply By	To Get
Horsepower (hp)	0.746	Kilowatts (kW)
Kilowatts (kW)	1.34	Horsepower (hp)

Area Conversions

Table 9-8. Area Conversion Units

Have	Multiply By	To Get
Square inches (sq.in.)	6.4516	Square centimeters (sq.cm)
Square inches (sq.in.)	645.2	Square millimeters (sq.mm)
Square centimeters (sq.cm)	0.155	Square inches (sq.in.)
Square millimeters (sq.mm)	0.00155	Square inches (sq.in.)
Square millimeters (sq.mm)	100	Square centimeters (sq.cm)

9.0 Appendix

9.2 FlowCom Digital Inputs and Outputs

FlowCom has a number of digital signals that may be added to WinDyn current data displays.

Refer to the Screen Display Editor section in the WinDyn Users Guide for details on how to create a screen object.

Status Indicators

These digital signals can be assigned to on-screen status indicators and used to display various digital (i.e., on/off) system conditions.

Table 9-9. Status Indicators

Input #	Function	On	Off
1	Simple/Advanced Mode	Simple	Advanced
2	High Temp Limit	Tripped	OK
3	Low Temp Limit	Tripped	OK
4	Remote EPROM error	Error	OK
5	EPROM Save Active	Saving	Off
6	Blower Motor Status	On	Off
7	Freeze State (Record)	Paused	Off
8	Unused	N/A	N/A
9	Intake/Exhaust Mode	Exhaust	Intake
10	Custom DTC	Yes	No
11	Line Frequency	60 Hz	50 Hz
12	Swirl Source	Torque	Frequency
13–64	Unused	N/A	N/A

9.0 Appendix

FlowCom Digital Relays (Switches)

These digital relays can be assigned to on-screen buttons used to control various system functions.

Table 9-10. FlowCom Digial Relays

Relay #	Function	Off -> On	On -> Off	Switch Type
1	Blower Motor Power	On	Off	On/Off
2	Unused	N/A	N/A	N/A
3	Record Data Line	N/A	Record	Momentary
4	Intake/Exhaust Mode	N/A	Toggle	Momentary
5	Auto-Record Function	Start	Stop	On/Off
6	Erase Last Data Line	N/A	Erase Last	Momentary
7	Erase All Data Lines	N/A	Erase All	Momentary
8	Increment Flow Range	N/A	Increment	Momentary
9	Decrement Flow Range	N/A	Decrement	Momentary
10–32	Unused	N/A	N/A	N/A

Table 9-11. Test Orifice Ranges and Pressure

Relay #	Function	Off -> On	On -> Off	Switch Type
SF-110/120	9	10” H_2O (25 cm)	150	153
SF-300	5	25” H_2O (63.5 cm)	240	246
SF-750	4	25” H_2O (63.5 cm)	240	246
SF-1020	6	25” H_2O (63.5 cm)	240	246
SF-1200	2	25” H_2O (63.5 cm)	240	N/A

* The values shown here are nominal only. Actual values may depend upon the flowbench calibration.

SuperFlow DYNAMOMETERS & FLOWBENCHES A Division of Power Test, Inc.

9.0 Appendix

9.3 FlowCom Code Default Worksheet

FlowCom Code Default Worksheet				
FlowBench Type	**SF-260**	**SF-750**	**SF-1020**	
Revison B April 16,2019 Dan G				
				Units
Default Full Scale Flow Pressure	5	21	14	InH20
Default Calibration Test Pressure	10	25	25	InH20
Full Scale Intake Range 1	15	45	25	CFM
Full Scale Intake Range 2	30	90	50	CFM
Full Scale Intake Range 3	45	190	100	CFM
Full Scale Intake Range 4	60	380	150	CFM
Full Scale Intake Range 5	90	570	200	CFM
Full Scale Intake Range 6	130	750	300	CFM
Full Scale Intake Range 7	160	na	400	CFM
Full Scale Intake Range 8	215	na	500	CFM
Full Scale Intake Range 9	280	na	700	CFM
Full Scale Intake Range 10	na	na	1000	CFM
Full Scale Exhaust Range 1	15	45	25	CFM
Full Scale Exhaust Range 2	30	90	50	CFM
Full Scale Exhaust Range 3	45	190	100	CFM
Full Scale Exhaust Range 4	60	380	150	CFM
Full Scale Exhaust Range 5	90	570	200	CFM
Full Scale Exhaust Range 6	130	750	300	CFM
Full Scale Exhaust Range 7	160	na	400	CFM
Full Scale Exhaust Range 8	215	na	500	CFM
Full Scale Exhaust Range 9	280	na	700	CFM
Full Scale Exhaust Range 10	na	na	1000	CFM
P-Gain Pressure	50	50	100	
I-Gain Pressure	50	50	100	
P-Gain Flow	50	50	100	
I-Gain Flow	50	50	100	

9.4 Parts Lists

Table 9-12. Options and Accessories

Quantity	Description	Part Number
2	Blower motor, intake†	F3815P-7505
2	Blower motor, exhaust†	F3815P-7522
1	FlowCom complete assembly‡	1200A-2200-05
2	Fuse, 1 Amp	E4320P-312001
1	Cable, USB, 10ft	E4330P-1054
1	Cable, CAT-5, 3ft	E4330P-04503
132	Tubing, clear vinyl (order by the inch)	F2500P-0120
1	Label, brass tube connection	F4900P-0002
1	AC power adapter, wall plug	E4190P-3590

† Flowbench motors are wired in pairs and should always be replaced as pairs. The flowbench has a total of 4 motors.

‡ Replacing the FlowCom panel will require the full-scale range values to be entered for the flowbench and the pressure transducers calibrated (SuperFlow can do both).

9.0 Appendix

9.5 Suggested Additional References

Books

Gas Flow in the Internal Combustion Engine, W.J. Annand and G.E. Roe, Haessner Publishing, Inc., 1974 (ISBN: 0070377200).

Haessner Publishing Co. (Search Engineering Library).

How to Build and Modify Small Block Chevrolet Heads, David Vizard, HP Books, 1991 (ISBN-10: 0879385472, ISBN-13: 978-0879385477).

How to Hot Rod Small Block Chevys, Bill Fisher & Bob Waar, HP Books, 2002 (ISBN-10: 0912656069, ISBN-13: 078-0912656069).

The Internal Combustion Engine in Theory and Practice, Charles Fayette Taylor, 2nd edition, John Wiley & Sons, N.Y., N.Y. (ISBN 0262 700166).

Internal Combustion Engines, Edward F. Obert, 2nd edition, International Textbook Co., Scranton, PA (Search Engineering Library).

Internal Combustion Engine Fundamentals, J. B. Heywood, McGraw Hill, New York, NY, 1988 (ISBN 0-07-028637-X).

Applied Combustion, Eugene L. Keating, 1993 (ISBN 0-8247-8127-9).

Scientific Design of Exhaust and Intake Systems, P. H. Smith and J. C. Morrison., Robert Bentley Incorporated, Cambridge MA, 1971.

The Sports Car Engine, Colin Campbell, Robert Bentley, Inc. (out of print, Public Library).

The Theory and Practice of Cylinder Head Modification, David Vizard, 1973, Classic Motorbooks, Osceola, WI, call (800) 826-6600 to order.

S.A.E. Technical Papers

S.A.E. technical papers may be obtained by contacting:

Society of Automotive Engineers, Inc.
400 Commonwealth Drive
Warrendale, PA 15096
(412) 776-4841

Request a current year catalog or order by number, author, and paper title listed below.

650448* *A Study of Engine Breathing Characteristics*, 1965, C. H. Wolgemuth and D. R. Olson.

700122* *Research and Development of High-Speed, High-Performance, Small Displacement Honda Engines*, 1970 by S. Yagi, A. Ishizuya, and I. Fujii.

720214* *Design Refinement of Induction and Exhaust Systems Using Steady-State Flowbench Techniques*, 1972 by G.F. Leydorf, Jr.

790484* *Analysis of the Volumetric Efficiency Characteristics of Four-Stroke Cycle Engines Using the Mean Inlet Mach Number*. February-March 1979 by Itaru Fakutani & Eiichi Watanabe.

820154* *AirFlow through Poppet Inlet Valves – Analysis of Static & Dynamic Flow Coefficients*, February 1982 by Itaru Fakutani & Eiichi Watanabe.

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820410* *A Study of Gas Exchange Process Simulation of an Automotive Multi-Cylinder Internal Combustion Engine*, February 1982 by Masaaki Takizawa, Tatsuo Uno, Toshiaki Oue, Tadayoshi Yura.

820749* *Valve Events and Engine Operation*, 1982, by T. W. Asmus.

830151* *Exhaust Valve Geometry and Its Effect on Gas Velocity and Turbulence in an Exhaust Port*, 1983, by S. G. Oldfield and N. Watson.

830226* Characterization of Flow Produced by a High-Swirl Intake Port, 1983, by T. Uzkan, C Borgnakke, and T. Morel.

900058* *An Experimental Study of Velocity and Reynolds Stress Distributions in a Production Engine Inlet Port Under Steady Flow Conditions*, 1990, by R. S. W. Cheung, S. Nadarajah, M. J. Tindal, and M. Yianneskis.

Bosch Automotive Handbook, from SAE Publications.

American Society of Mechanical Engineers Publication

United Engineering Center, 345 East 47th Street, New York, NY.

76-WA/DGP-4

Short Pipe Manifold Design for Four-Stroke Engines, December 1976, P. C. Vorum

9.0 Appendix

9.6 Drawings

The following pages contain information specific to the SuperFlow equipment ordered. As specifications and part numbers change, these documents will be updated to reflect the equipment and requirements for your machine at the time of shipment. Contact your sales representative for further information.