INFRARED INDUSTRIES


# HM5000

## Handheld Gas Analyzer

# USERS GUIDE


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# Chapter 1

## Introduction

The HM5000 exhaust gas analyzer allows the measurement of four or five gas components in combustion exhaust.

It is capable of determining volume concentrations of HC (as N-hexane), CO (carbon monoxide), $CO_2$ (carbon dioxide), $O_2$ (oxygen), and optionally $NO_x$ (nitric oxide).

Based on gas concentrations the analyzer will calculate the Air to Fuel Ration (AFR), Lambda ($\lambda$) and Grams per Mile (GPM) or Grams per Kilometer.  It will also provide a read-out for the optional Tachometer that reads up to 30,000 RPM.  With this much information in one place, you can diagnose and tune any fuel-related issues while having all of the relevant information displayed in a super-bright graphic LCD screen.In addition to the above features, the analyzer can measure exhaust gases from two tail pipes and average the readings, or set up an exhaust dilution value to warn you if there are air-leaks in the exhaust system.

Weighing less than 2 pounds, the HM5000 is intended for use in a variety of indoor or outdoor environments. The analyzer can be plugged into standard power outlet voltages either 100 VAC to 260 VAC, 50/60 Hz. It also has a rechargeable nickel metal hydride battery internal power pack so you can take it along for a drive test to see how the vehicle behaves in real driving situations.  Using the internal record feature you can store the data during the test drive and download the information to a PC or PDA when you return.

Chapter

2

# Setup

This section provides a description of the set-up of the analyzer.  When you are setting up the analyzer for the first time, check for any damage that may have occurred during shipping. The standard accessory kit should include a sample hose, sample probe with a detachable handle, power supply, manual, and Quick Guide.

### Power Up

The analyzer can be operated from AC, DC, or cordless power sources.  For external DC power the analyzer will operate on 10-16 VDC.  For cordless operation the analyzer will run off its' own internal rechargeable lithium battery pack.

The AC power-input connection is a standard 3-wire recessed computer-type connector.  Various types of power cords may be used to connect to an AC outlet.  Each will have a different connector to be compatible with the various supply voltages and country outlet styles.

1. Attach the power cord to the bottom of the analyzer and plug the end of the cord into the appropriate power source. The 12VDC cable can be plugged into a cigarette lighter or clipped to the battery for DC power. The Power Indicator will illuminate red when power is present.

2. Make sure that the sample probe has been placed in an area where there is only air to be drawn into the sample line.

3. Press the **ON/OFF** button to turn on the unit.

*Note:  Before using the HM5000 for the first time, refer to Chapter 4 and 5 for information on configuring and operation of the analyzer.*

### Zeroing The Analyzer

The HM5000 will take approximately 30 seconds to warm-up, purge itself, and enter into the standby mode. The analyzer should then be zeroed once just prior to measuring the exhaust. The analyzer and probe should be kept clear of the exhaust steam until this point. Emersion into the exhaust stream before this point will severely affect the accuracy of the analyzer.

After the warm-up cycle is completed and the probe is in the tailpipe, press the **PUMP** key to begin measurements.

*Note:  Check the flow indicator to make sure you have sufficient flow.*

Chapter

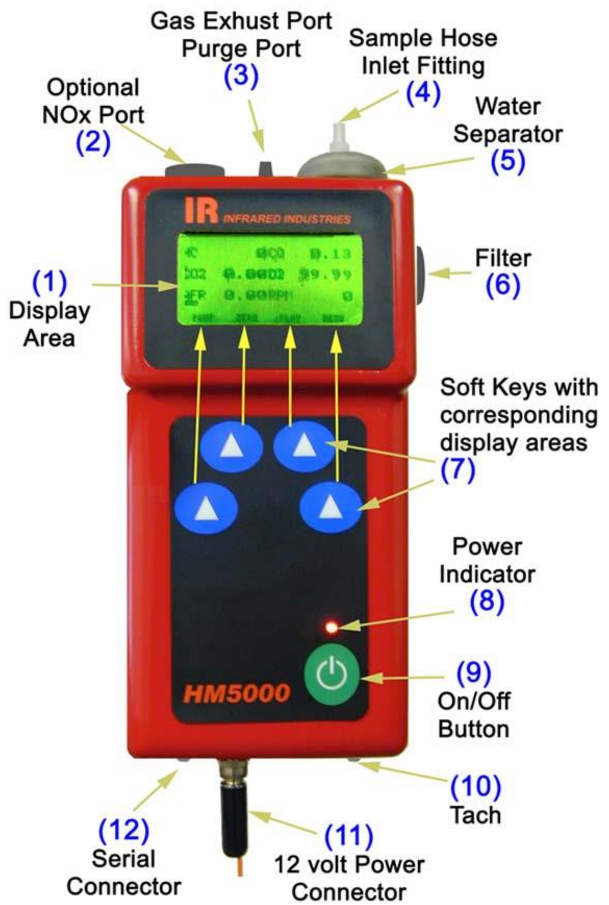
3

## Display Features

Before attempting to operate the analyzer, review the system features described below as well as all warning labels. Identification and understanding of the physical features of the instrument will make operation easier.

After plugging in the HM5000 Gas Analyzer, the POWER INDICATOR (8) is lit indicating that power is available. Press the ON/OFF button (9) to turn on the unit. During power-up, the status bar in the DISPLAY AREA (1) indicates the calibration of $O_2$. When this is complete, the operator **MUST** zero the analyzer using the corresponding SOFT KEY (7).

You can begin measuring gas concentrations by connecting the sampling hose/probe assembly to the SAMPLE HOSE INLET FITTING (4) located on the top of the analyzer. Insert the sampling probe to a gas source or an exhaust stream. Press PUMP using the corresponding SOFT KEY (7) to begin sampling of the gases. Allow a few seconds for the gases to reach the analyzer. While the pump is on, you can hold or freeze the display values by pressing the corresponding SOFT KEY(7).



Chapter

4

# Configuring the Analyzer

After plugging in the HM5000 the Power Indicator will be illuminated confirming that there is power to the analyzer - the power supply is properly attached or the unit's battery is charged. Press the **On/Off** button to activate the analyzer. During the initial power-up, the pump will come on briefly and there will be a status bar at the bottom of the screen to indicate the calibration of O2. When this is complete, the Standby Screen will appear. The operator MUST zero the analyzer using the corresponding soft key before exhaust gas testing. Refer to Chapter 3 "Display Features" if you are not sure which button to use.

### STANDBY SCREEN

| | | | | |
|---|---|---|---|---|
| CO | | O2 | | Standby Screen |
| CO2 | | HC | | |
| RPM | | LAM | | The HM5000 will return to this screen after exiting the menu selection. It is possible to customize the display screen settings by going to Display Settings in Menu 2. This allows the operator to select one or as many as all of the values to be displayed on the screen. |
| AFR | | RPM | | |
| PUMP | ZERO | PLAY | MENU | |

**Pump** – Allows manual on/off operation of the pump. This function can also be used to purge gas from the analyzer. For more detailed information, please refer to the section "Identifying Actions When Pump Is On".

**Zero** – Zeros the analyzer for approximately 1 minute. The pump is automatically controlled during this phase.

**Play** – Plays back recorded data. Choose **Pause**/**Continue** to control the play function or **Exit** to return to the Standby screen.

**Menu** – Use this button to access Menu 1

### IDENTIFYING ACTIONS WHEN PUMP IS ON

| | | | | |
|---|---|---|---|---|
| CO<br>CO2<br>RPM<br>AFR<br><br><br><br>PUMP | <br><br><br><br><br><br><br>PRINT | O2<br>HC<br>LAM<br>RPM<br><br><br><br>HOLD | <br><br><br><br><br><br><br>RECORD | Measure Screen<br><br>The HM5000 will display this screen when Pump is selected from the Standby screen. It is possible to customize the display screen settings by going to Display Settings in Menu 2. This allows the operator to select any or all of the values shown to be displayed on the screen. |

**Pump**
Selecting **PUMP** allows the operator to turn the pump on and off. When the pump is off, the display will return to the Standby screen. To start the pump when measurement of gas concentration is desired simply select **Pump**. Once the pump has been turned on the screen menu will change from **PUMP**, **ZERO**, **PLAY**, and **MENU**, to **PUMP**, **PRINT**, **PLAY**, and **RECORD**. Pressing the **PUMP** key once more while the pump is running will stop the pump and return you to the standby menu.

**Record**
The analyzer has the ability to store data by selecting **RECORD**. The recorded information will remain in memory until erased. To erase the data in memory enter into the **Menu 1** options and select **Erase Data**. Once you have selected this option you will be asked if you wish to erase stored data. Select **YES** to erase data or **NO** and return to the standby screen.

**Hold / Resume**
Selecting the **HOLD** key will lock the display values to capture that moment in time. Once the **HOLD** key has been initiated the **HOLD** enunciator will change from **HOLD** to **RESUME**. To return to normal operation press the **RESUME** key and return to a live display.

**Print**
Prints data to a printer connected to the serial port located at the bottom of the analyzer.

**MENU 1**

| | |
|---|---|
| Grams/Sec<br>GPM Test<br>Factor Cal Reset<br>Calibration<br>Serial Port<br>1<br><br>EXIT ∨ ∧ ENTER | **Menu 1**<br><br>Use the **UP** or **DOWN** soft keys to select an action. Press **ENTER** to access the menu for that action. Press **EXIT** to return to the Standby screen. |

**Grams/Sec-** See Chapter 8 for a description of this menu option.

**Erase Data** – Select this option to erase data. Select either **Yes** or **No** to erase data and return to the Standby screen.

**GPM Test** – In **GPM Test** mode the analyzer will measure the gas concentrations over a fixed amount of time and, based on the distance traveled, will compute and display the grams per mile (or kilometer) used. Refer to Chapter 5 for details on using this feature.

**Factory Cal Reset** – Select **Yes** to reset the factory calibration settings and automatically return to the Standby screen or **No** to go directly back to Standby.

**Calibration** – Once Calibration menu option has been selected, the analyzer will purge itself, perform a zero, and then proceed to the next step. When zeroing is complete, you will be prompted to **Enter Tag Values**. The tag values should be entered just as they are on the calibration bottle. You are not required to calculate the PEF value for HC. Instead enter the propane value and the analyzer will internally convert it to a hexane HC value. When entering tag values for CO and CO2 are entered are percentages. For HC and NOx, values are entered as ppm. Any gas you do not wish to change the calibration on should be set to --- which indicates no value change. O2 is self calibrating on atmospheric O2 (air). To enter the tag values of your calibration gas, use the **GAS** key to select the gas. Press **+** to change the value of the highlighted numeral and select the **NEXT** key to advance to the following numeral. When finished, press **Continue** to advance to the next sequence serene. The screen will prompt you to **Turn Cal Gas On** and all the values will be shown below. Once the cal gas has been turned on, wait for the values to rise and stabilize then press **Continue**. This is when the analyzer performs its actual calibration. Do not disturb the analyzer during this period or the accuracy of your calibration could be jeopardized. When calibration is complete, you will be prompted to **Turn Calibration Gas Off**. When this is completed, press **DONE**, the analyzer will turn on its pump, purge itself, perform an automated zero, and return to the Standby screen. The analyzer is now ready to resume service.

**Serial Port** – This option defines what is connected to the serial port. The two choices are **PC** (to connect to a PC or PDA) or **PRINTER** to connect to an external printer.

**MENU 2**

| | |
|---|---|
| Display Settings –<br>Exhaust Dilution –<br>RPM Settings –<br>Display Values –<br>[2]<br><br>EXIT UP DOWN ENTER | Menu 2<br><br>Use the **UP** or **DOWN** soft keys to select an action. Press **ENTER** to access the menu for that action. Press **EXIT** to return to the Standby screen. |

**Display Settings** – Allows the operator to set degree of Backlight and Contrast. Select the **Light** key to change the amount of backlight, the **Up** key for more contrast, and the **Down** key for less contrast. Select **EXIT** to return to the Standby screen.

**Exhaust Dilution** – Provides the operator with a warning in the Measure Mode that the probe may not be positioned properly or that there may be a leak in the exhaust system of the vehicle. Select **Enable** or **Disable** and automatically return to the Standby screen.

**Dual Exhaust** – This selection puts the analyzer into dual exhaust mode where the right and left exhaust measurements will be averaged. Follow the instructions on the screen or press **EXIT** to return to the Standby screen.

**RPM Settings** – Allows the operator to select between 2-stroke and 4-stroke engine configurations.

**Display Values** – Allows the operator to customize the display on the Standby screen. Use the **ENTER** key to select the desired position and the **+** key to scroll to the desired value using **---** to indicate no value to be displayed.

**MENU 3**

| System Information – / Record Time – / Time and Date - / Leak Check - [3] / EXIT UP DOWN ENTER | **Menu 3** Use the **UP** or **DOWN** soft keys to select an action. Press **ENTER** to access the menu for that action. Press **EXIT** to return to the Stand By screen. |
|---|---|

**System Information** – This screen contains information about your system: PEF (propane equivalency factor), the serial number and software version. Press **DONE** to return to the Standby screen.

**Record Time** – Allows the operator to select a specific recording period or to choose manual start/stop. To enter the amount of time you wish to record, use the **NEXT** key to select the desired position and the **+** key to scroll to the desired value. If manual operation is desired, specify the value as 0.00. After the time is set, select **EXIT** to return to the Standby screen. Once the **PUMP** is turned on, **RECORD** will appear in the lower right corner. Press **RECORD** when you wish to begin recording. The recording period will end automatically once the selected time has expired. If you have set the time for manual control, press **RECORD** when you want to stop recording.

Chapter

5

# Using the Analyzer

## MEASURING GAS

### Pump

Selecting **PUMP** turns on the pump. The system will process the analyzer signals, converting them to concentrations and displaying these concentrations (and Lambda when this option is present) on the display. The **AUTO ZERO** function is locked out in this mode. The **SAMPLE/ZERO** solenoid is in the **SAMPLE** state which is de-energized or normally. This is when exhaust gas sample is being measured, provided the sample probe is inserted into the tailpipe. The **PUMP** enunciator will be highlighted. Exhaust will be drawn into the analyzer, measured and expelled.

### Hold

If it is desired to “freeze” the readings on the screen while in the **PUMP** in on, press the **HOLD** key will “freeze” the reading on the display and the concentration values will not be updated while the display is “frozen. Once activated the **HOLD** enunciator will be replaced with the **RESUME** enunciator key. Selecting the **RESUME** key will return the analyzer to standard operation.

### Print

This feature is for use when a printer is plugged into the serial port on the analyzer. The printer will print the information on the screen any time the **PRINT** key has been pressed.

### Recording Data

When the **PUMP** key is selected the menu will change and **RECORD** will appear on the lower left-hand side of your screen. Pressing the record key will engage the recorder on the analyzer as indicated by the highlighted **RECORD** indicator. The recorder will disengaged when the pump is turned off but the recorded data will stay in memory until the **Erase Data** menu option is accessed. When the **Erase Data** option is opened, you will be asked “Are you sure you want to erase the stored data?” Select **YES** to erase and **NO** to save the data and return to memory. The **Erase Data** option can only be accessed if the is data stored in memory if not selecting the option will simply return you to standby. To play back the recorded data select **PLAY** key on your display. When the **DISPLAY** key is selected the stared data will play back to the screen in the same order it was recorded. When playing back multiple tests, there will be a slight pause between the playback readings to denote the start of a new test.

## CALIBRATION

The analyzer as shipped has been calibrated at the factory and is designed to maintain calibration accuracy for extended periods of operation. Due to the sophisticated circuitry used in the analyzer, frequent calibration is not required. However, we recommend a gas calibration about every three months to ensure the integrity of the analyzer. Some states have regulations governing the time intervals between calibrations. It is important to comply with the governing regulations for your locality.

*NOTE: When using calibration gas, the bottle should be kept at about 21°C [70°F] for 8 hours prior to use. Sudden temperature changes can condense some of the components in the bottle, changing their concentration.*

### Calibration Gas and Regulator

A bottle of calibration gas is required to check analyzer calibration and to perform calibration. For the high-pressure cylinders of gas, a regulator is needed to monitor the pressure of the calibration gas bottle and to regulate it to the pressure required for testing and calibration.

Calibration gas has a known concentration of HC, CO, $CO_2$, and NOx where applicable. The gas is available in a range of concentrations. We recommend using calibration gas of the following concentrations when checking or calibrating the HM5000 Gas Analyzer:

- HC (propane) 1200ppm
- $CO_2$ 12.0%
- CO 4.0%
- Balance N2

Note: We list balance N2 here because we recommend that $O_2$ be calibrated using air during AUTO-ZERO.

These values are the default values for the analyzer, which are automatically displayed when initiating the calibration procedure. Using calibration gas with these concentrations eliminates having to enter new values during the calibration procedure.

If you choose to use cal gas with different concentrations, it must be within the following ranges:

- HC (propane) 140 ppm to 3400 ppm
- $CO_2$ 5% to 15%
- CO 0.9% to 8.5%

### Field Calibrating the Analyzer

The analyzer does not need regular field calibration. However, field calibration can be performed when there is reason to believe that the factory calibration is no longer producing accurate analysis results.

The gas analyzer does not require gas calibration very often. Therefore the gas calibration tanks are normally closed. It will be assumed in the calibration process described below that the calibration gas is turned off at the tank.

> ***CAUTION: WHEN CALIBRATING OXYGEN WITH CAL GAS (other than ambient air), THE INTERVALS BETWEEN CALIBRATIONS FOR THE OXYGEN SENSOR WILL BE CONSIDERABLY FURTHER APART - DAYS, WEEKS, OR MONTHS DEPENDING ON HOW OFTEN THE UNIT IS GAS CALIBRATED, AS COMPARED TO THE AUTO ZERO CYCLE PERIODS (MINUTES). BECAUSE THE ANALYZER IS INHERENTLY SPAN STABLE, IT IS BEST IF THE OXYGEN SENSOR IS ALLOWED TO SELF CALIBRATE AUTOMATICALLY ON AMBIENT AIR DURING THE AUTO ZERO CYCLE RATHER THAN TO USE CAL GAS.***
>
> *NOTE: The oxygen sensor and circuitry do not need calibration; they are checked automatically during zeroing. If the sensor deteriorates to the point of needing replacement, a Zero Failure may occur after zeroing.*

To perform a calibration enter the menu options and scroll down to Calibration and then press the **ENTER** key to select it. The analyzer will zero itself tell you to Please Standby Zeroing Analyzer and then proceed to the next calibration sequence screen called **ENTER TAG VALUES**. At this sequence all the gases are listed with the first numeral of the HC value highlighted. To change gas values scroll the highlighted number up using the **+** key and then press the **NEXT** key to continue on the next numeral. Once the HC value has been set you can advance onto the next gas by pressing the **GAS** key. Once all the values have been set press the **CONTINUE** key to advance to the next sequence screen. The next screen that appears tells you to **TURN CAL GAS ON** will all the gas shown below. Connect your calibration gas to the inlet port of your analyzer with the regulator set to 3 psi and watch for the gas values in the display to clime. When the gas values stop climbing and stabilize press the **CONTNUE** key to move on. The analyzer will say **CALIBRATING** at the top of the screen. Do not disturb the analyzer during this period; this is when the actual calibration is taking place. When the calibration is complete the analyzer prompt you to "**Turn Calibration Gas Off**", now turn the cal gas off, disconnect your cal gas line, and press the **DONE** key. The analyzer will now turn on its pump and purge itself, perform an automated zero, and return to standby. The calibration is now complete and ready for use. During the calibration process you can escape back to standby at any time by selecting the **EXIT** key.

### DUAL EXHAUST

Select the **Dual Exhaust** by entering the menu options and scrolling down to **Dual Exhaust** on Menu 2. Pressing the **ENTER** key will then select that option where you will be prompted to "Insert Probe In First Exhaust Then Press Start". When this has been done press the **START** key and the pump will turn on. The screen will change and your reading will be displayed. Wait for the reading to stabilize and then press the **STOP** key. This will store the first reading in memory and prompt the operator to "Insert Probe In Second Exhaust Then Press Start". As before, wait for the reading to stabilize and then press the **STOP** At this point the displays will show the average of the two exhaust pipe readings. Pressing the **DONE** key at this time will return you to the normal standby screen.

## TACHOMETER

The Tachometer readings can be added to the display values through the **Display Values** options window listed in your analyzer Menu 3. The **RPM** value setting can be adjusted for 2-cycle or 4-cycle through the **RPM Settings** in your menu display options by selecting the RPM Settings key in your menu options.

## ZEROING

In the zeroing process, the analyzer corrects itself for temperature and atmospheric pressure variations that continually change trough the course of the day. Zeroing on the ambient air will remove any background gases in the analyzers' environment. The analyzer will then establish a new baseline or zero state based on the current state. Care must be taken to keep the analyzer in fresh air during operation and to vent the discharging exhaust clear of its environment.

### Manual Auto-Zero

The operator may initiate an auto-zero cycle any time the system is in **STANDBY.**

### Auto-Zero Sequence

In the AUTO ZERO mode

1. The sample pump is turned on,
2. The SAMPLE/ZERO solenoid is switched to the ZERO GAS and the sample cell is purged completely,
3. The system acquires and stores new zero data

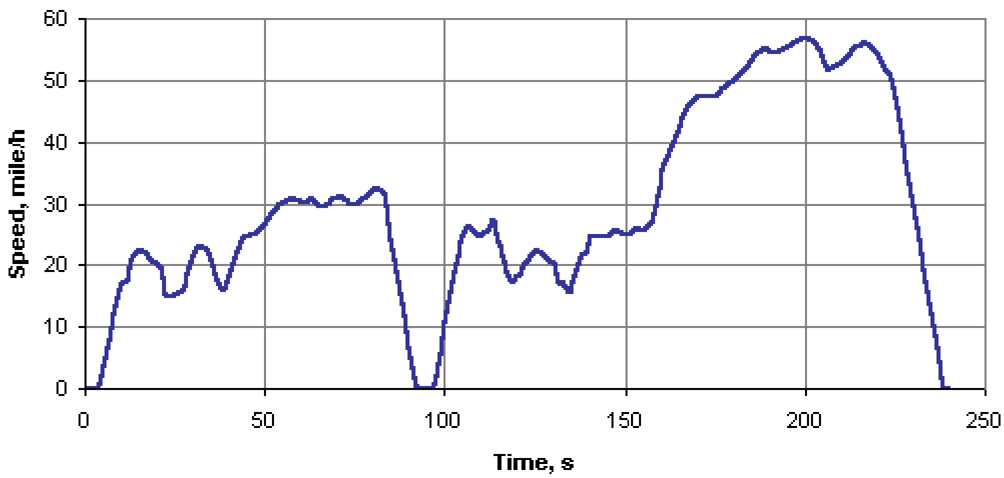
During this process the **ZERO** the analyzer will display the message "**Please Standby Zeroing Analyzer**" and all other functions will be locked out.

The **AUTO ZERO** cycles last about 25 seconds.

## GRAMS PER MILE (KILOMETER)

**GPM** is a menu option on screen 1 and implements an approximation to the IM240 tests. In this mode you will be prompted to enter the beginning odometer reading and engine displacements (in liters). Once this information is entered the test begins and the IM240 driving pattern is driven or simulated on a dynamometer. After the test is complete the ending odometer reading is entered and the test results are displayed in grams per mile (or kilometer). See Appendix C for details on this option.

About 30 states presently require smog checks of vehicles and, of these, only about 7 require in IM240 tests. The IM240 test uses a dynamometer in a varying driving pattern, and gives the results in grams per mile (kilometer). The IM240 driving pattern lasts for 240 seconds and involves the speed changes s shown in the graph on the next page.




The first 94 seconds of this pattern re sometimes referred to as a fast-pass test. If all of the limits for gm/mile for the gases being tested are met during this phase, then the vehicle passes the test and the more extensive 240 second drive test is not conducted.

This driving test can be approximated without a dynamometer by conducting a road test instead and taking data using the Infrared Industries model HM5000 gas analyzer. To perform this test, follow the steps below.

### THE 94 SECOND FAST-PASS TEST APPROXIMATION

1. Position the vehicle under test (VUT) on a flat road with an uninterrupted length approximately 1 mile (or place it on a dynometer). The VUT and catalytic converter must be up to temperature.
2. Connect the tachometer and exhaust gas inputs to the HM5000.
3. Start the test by pressing the **GPM Tes**t button from Menu 1. The display will now prompt you to **Enter Engine Displacement**. Use the **Next Ch** option to go to the next digit and **+** to increase the value of the current digit. When you are finished entering the Engine Displacement, select **Next** to continue to the next screen.
4. You will then be prompted to **Enter Odometer Reading**. Use the **Next C**h option to go to the next digit and **+** to increase the value of the current digit, using **---** to indicate no value to be displayed.
5. When you are finished entering the Odometer Reading, select **Next** to continue to the next screen.
6. Following the instructions on the screen, **Press Start to Begin Test** and **Press Stop to End Test**. The run time will automatically be displayed on the screen during the test.
7. You will then be prompted to **Enter Odometer Reading**. Use the **Next Ch** option to go to the next digit and **+** to increase the value of the current digit using **---** to indicate no value to be displayed.
8. When you are finished entering the Odometer Reading, select **Next** to continue to the next screen.
9. Your test results will then be displayed on the screen. Press **Done** to return to the **Standby** menu.

**EXHAUST DILUTION**

The **EXHAUST DILUTION** function provides the operator with a warning in the **MEASURE** mode that the probe may not be positioned properly or that there may be a leak in the exhaust system of the vehicle. It is common to have the hose probe come out of the exhaust because the hose was kicked or for some other reason. The **EXHAUST DILUTION** function is meant to warn the operator that this has happened.

The warning is based on the measurement of $CO_2$. Typically vehicle exhaust has anywhere form 16 to 25% $CO_2$. If the $CO_2$ is ever below 12%, when it should be measuring vehicle emissions, it is most likely because the probe has fallen out. Therefore the system checks to make sure that there is at least 12% $CO_2$ in the gas in the sample cell when in **MEASURE** mode. If not, it flashes the **EXHAUST DILUTION** indicator.

The feature can be enabled or disabled by the operator. The default is that **EXHAUST DILUTION** is "DISABLED" and that the threshold is 12%.

The function is enabled and disabled through the **EXHAUST DILUTION** option in the menu. The operator has an opportunity to modify the **EXHAUST DILUTION** threshold, by selecting the **EXHAUST DILUTION** option and then selecting **ENABLE**. The **Exhaust Threshold** value will be shown on the display with the first numeral highlighted. The operator can select the **-** and **+** soft keys and the **EXHAUST DILUTION** threshold will increases or decreases its value, selecting **NEXT** will advance you to the next numeral. When the operator has the value he wants to use (we recommend 12%), pressing **DONE** will save the **EXHAUST DILUTION** threshold value and exit the menu feature. The analyzer has now returned to its ready state and the system now has the **EXHAUST DILUTION** active.

**GRAMS PER SECOND**

This test is run from the Menu option “Grams/Sec”. It measure the gas readings over a period of time and calculates the average grams per second over the timeframe. Under the Menu options when “Grams/Sec” is selected the following sequence of screens appear:

**Enter Test Time**

**0000**

**Exit** **Next** /\ **Continue**

This screen shows the number of seconds the test will run. You can modify the time by using the ^ button and the Next button. The Next button advances to the next numeric field while the ^ button increments the current numeric value in the selected field. The analyzer will record the value entered here and display it as the run time in future tests. When you have completed selecting the time press Continue.

**ENTER ENGINE**
**DISPLACEMENT – Liters**
**0.0**

**Exit** **Next** /\ **Continue**

In this screen you will need to enter the engine displacement in liters. The buttons work in the same manner as the prior screen. When you have completed entering the displacement press Continue.

**ENTER RPM**
**ENTER ZERO TO USE TACH**

**0000**

**Exit** **Next** /\ **Continue**

In this screen you will need to enter the RPM reading for the test. If the value is left as zero the reading from the TACH will be used. When you have completed entering the RPM press Continue.

**PRESS START TO**

**RUN TEST**

**Exit** **START**

At this point all information has been entered for the test. When you are ready to start the test press START. If you do not want to run the test press Exit to return to Standby.

**AVERAGED GRAMS/SEC**

**HC** **nn.nn** **CO** **nn.nn**

**CO2** **nn.nn** **O2** **nn.nn**

**Exit** Counter: nnn

This screen will display the current grams per second value in one second intervals. If you want to abort the test press Exit and the analyzer will go back to standby mode.. The counter value displays the remaining time of the test.

| GRAMS/SEC RESULTS | | | |
|---|---|---|---|
| **HC** | **nn.nn** | **CO** | **nn.nn** |
| **CO2** | **nn.nn** | **O2** | **nn.nn** |
| **Exit** | | **Continue** | |

When the test is completed (the time has elapsed) the average readings for each gas will be displayed. Press Exit to return to standby mode. If you want to run another GPS Test press Continue

Chapter

6

# Maintenance

The analyzer requires very little maintenance. The following chart itemizes the schedule for those items that do require periodic maintenance.

| Component | Interval |
|---|---|
| Zero Vacuum Probe | Each Use |
| Sample System Hose | Check As Required |
| Filter | When a LOW FLOW indication appears* |
| Calibration | Check Every Three Months |
| Oxygen Sensor | Replace Every Twelve Months |
| Nitric Oxide Sensor (Opt.) | Replace Every Twelve Months. Requires calibration when replaced. |

*Service filters more frequently if analyzer is operating continuously.

### Checking and Cleaning the Probe

Periodically check the holes at the end of the probe for dirt and debris. Disconnect the hose from the analyzer at the sample inlet. Using a small pointed tool, clean the probe and blow away any debris, using compressed air.

> ***CAUTION**: DO NOT APPLY COMPRESSED AIR TO THE PROBE TIP WITHOUT DISCONNECTING THE SAMPLE HOSE FROM THE FILTER ASSEMBLY. BACK PRESSURE COULD DAMAGE THE SAMPLING SYSTEM.*

### Replacing the Probe

1. Remove the sample probe from the handle.
2. Install the new probe on the handle and tighten. Use only Teflon tape on fittings.

### Hose

The sample hose must be free of cuts and abrasions that may cause leaks.

### Filter Assembly

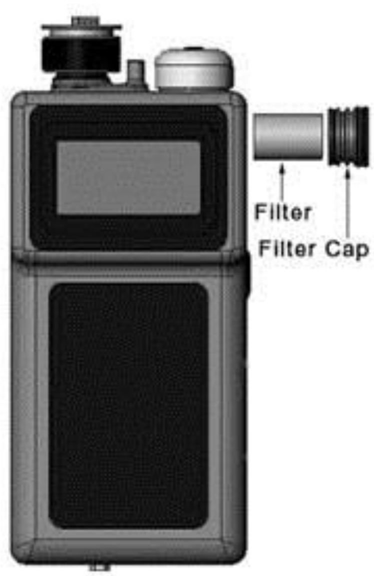
The filter assembly uses a single filter to keep the pump and internal sample system clean. The filter element removes all the contaminants from the exhaust sample. Exhaust gas flows through this filter element from the outside in, so contaminants collect on the outside of the filter element.

The exhaust gas sample enters the filter from the water separator. The exhaust enters the water separator through the sample hose port located at the top of the water separator. The water vapor contained in the sample gas condenses in the separator through a series of baffles where the water is then evacuated from the separator through the water purge port located at the base of the separator bowl by the system pump.

Filter service frequency is dependent on the operating conditions. Continuous use, testing vehicles that have not been warmed-up to normal operating temperature, or testing engines that have excessive emissions will require more frequent filter service.

**Replacing the Filter**

The primary filter element is an unwoven, disposable material. If debris builds up on the filter material, becomes discolored and the sample flow is reduced, the filter should be replaced.




1. Turn off power to the analyzer.
2. Remove the clear filter cap located on the upper right side of the analyzer by turning it counter-clockwise with a coin or screwdriver.
3. Replace the old filter with a new one. Use only IRI part number #10781 as a replacement filter.
4. Reinstall the filter by first lubricating the 2 o-rings on the cap with silicon grease then screw the cap down flush with the side of the analyzer. The filter cap slot should be inline with the analyzer case seam.

**Front Panel and Exterior**

To maintain the appearance of the analyzer, periodically clean the exterior with a soft damp cloth. Use a mild detergent to remove grease.

> ***CAUTION**: DO NOT USE CLEANERS SUCH AS ACETONE, BENZENE, CARBON TETRACHLORIDE, GASOLINE, OR TOLUENE, AS THEY CAN DAMAGE PLASTIC COMPONENTS AND AFFECT ANALYZER ACCURACY IF THEY CONTAMINATE THE SAMPLING SYSTEM.*

Gasoline, brake fluid, and penetrating oil spills should be immediately cleaned from the analyzer surface to protect its finish.

### Oxygen Sensor

The oxygen sensor used in the analyzer requires replacement every 12 months. Several faults can be caused by an expired or defective oxygen sensor including:

- Zero Failure in the after a zero procedure (manual or automatic).
- General Failure. This may occur if the wire harness to the $O_2$ sensor is not connected.

### Servicing the Oxygen Sensor

***NOTE: O****nce the shipping container can is opened, the sensor begins to deteriorate. Sensor life in open air is 12 months, regardless of how often the analyzer is used.*

1. Turn off the power to the analyzer.
2. Remove the 4 cap-screws on the back of the analyzer and lift off the back cover.
3. Disconnect the oxygen sensor connector from the circuit board.
4. Remove the O2 sensor from the side of the filter housing by turning the O2 sensor counter-clockwise and discard it.
5. Install the new sensor in the filter housing. Turn the sensor clockwise into the filter housing until the O-ring is seated.
6. Plug the sensor connector onto the circuit board, ensuring it is connected correctly.

***NOTE:*** *he connector is keyed so that it only plugs in correctly one way.* ***Do not*** *force the connector onto the board.*

### NOx Sensor - Oxide of Nitrogen

The NOx sensor used in the analyzer requires replacement every 12 months. Several faults can be caused by an expired or defective NOx sensor, including:

- Zero Failure in the after a zero procedure (manual or automatic).
- General Failure. This may occur if the wire harness to the NOx sensor is not connected.

### Servicing the NOx Sensor

1. Turn off the power to the analyzer.
2. Remove the NOx sensor connector from the top of the sensor.
3. Remove the NOx sensor manifold at the top of the analyzer. Turn the NOx sensor counterclockwise and remove it from the manifold.
4. Install the new sensor in the manifold by turning the sensor clockwise into the manifold until the O-ring is seated.
5. Install the sensor connector into the top of the sensor, ensuring it is connected correctly.

***NOTE:*** *he connector is keyed so that it only plugs in correctly one way.* ***Do not*** *force the connector into the sensor.*

**Routine Cleaning**
The analyzer should be cleaned routinely to prevent the build up of dirt, which can contaminate samples and mar the appearance of the instrument. Clean the case exterior and other accessible parts of the analyzer with a cloth dampened with warm water and mild soap.

## RETURNING THE ANALYZER FOR SERVICE

If the analyzer needs service, contact your dealer for complete instructions. If you need to ship the analyzer, pack it in its original container. We recommend that you insure the shipment.

To help in getting effective service, follow these guidelines:

1. Follow all instructions in this manual to be sure that the problem is with the analyzer and not with other equipment, sample purity, or cable connections.

2. If you determine that repair is required, contact the factory to receive Return Materials Authorization (RMA) number. This is required prior to sending the unit in for repair. Also, be sure to include the following items when returning the analyzer for service:

3. A description of the precise sample and operating circumstances.

4. A brief description of the symptoms.

5. The serial number.

6. Your name, address, and telephone number.

Chapter

7

# Troubleshooting

Analyzer Troubleshooting

There are three failure modes that the analyzer might encounter: General Failure, Zero Failure, and Failure to Calibrate.

***For a General Failure and Zero Failure, perform the following procedure:***

1. Verify that all the ports are unobstructed, including:
   - Cal gas
   - Zero
   - Sample hose
   - Drain hose
2. Verify that the O2 sensor wire harness is properly connected.
3. Replace the O2 sensor if it has been installed for more than 12 months, or if its age is unknown.
4. Check the filters.
5. If a failure is still indicated, service is required by an authorized IRI Analyzer service center.

***For a Failure to Calibrate, perform the following procedure:***

- Repeat calibration.
- If the analyzer still fails to be calibrated, the analyzer can still be used but it will be at reduced accuracy. It should be sent in for service when convenient.

When the default cal values are in use, the analyzer can still be used but the displayed values will be less accurate. It is recommended that the gas calibration procedure be performed to ensure accuracy.

| SYMPTOM | PROBABLE CAUSE | SOLUTION |
|---|---|---|
| Low sample flow | 1. Restrictions in sample hose or probe.<br>2. Restrictions in sample filter. | 1. Check for kinked, plugged or pinched hose or probe. Clean probe tip with a small pointed tool. Disconnect hose from sample inlet and blow out if necessary.<br>2. Service filter elements. |
| Low sample flow during zeroing. | Restriction in Zero port. | Check for obstructions in zero port |
| All function keys inoperative. | Microprocessor latch-up. | Turn analyzer power switch OFF and then back ON. |

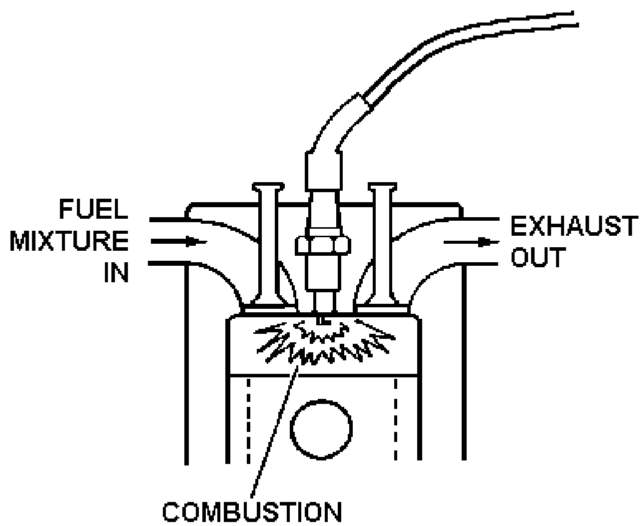
Appendix

# A

## Exhaust Gas/Emission

### COMBUSTION FUNDAMENTALS

*Figure 4* ***The Combustion Process***




To understand and interpret the information provided by the analyzer, it is helpful to have an understanding of what the analyzed combustion byproducts are, how and where they are formed in a gasoline engine, and the relationship between them at different air-fuel ratios.

In a gasoline-powered, internal combustion engine, normal combustion is the spark-ignition of a compressed mixture of hydrocarbon fuels and air, taking place in the combustion chamber. This action produces the pressure that forces the piston downward. Figure 4 shows the compressed air-fuel mixture being ignited by the spark plug.

The fuel induction system of a gasoline engine forms air-fuel mixtures by vaporizing gasoline (a hydrocarbon), and mixing it with air in a given proportion (always more air than gasoline vapor). There is 14 times as much air as fuel (by weight), needed to vaporize the fuel into a state for ignition and to supply enough oxygen to the fuel so it can burn in the combustion reaction.

### GAS FUNDAMENTALS

#### Lambda

The ideal air-fuel ratio for perfect combustion in a gasoline engine is 14.66:1, or 14.66 pounds of air to each pound of vaporized gasoline. This is known as a stoichiometric ratio or stoichiometric fuel mixture.

> ***Note:*** *Lambda ($\lambda$) is Air Fuel Ratio/14.66. This parameter is easier to use because it is 1.0 when the combustion is optimal. Lambda is less than one for "rich" combustion and greater than one for "lean" combustion. We will use Lambda in our discussion of combustion.*

Under perfect conditions the combustion of a stoichiometric air-gasoline mixture would result in carbon dioxide ($CO_2$), water vapor ($H_2O$) and nitrogen ($N_2$), which are all harmless combustion byproducts. Therefore if we measured the exhaust of a gasoline engine and found only $CO_2$, $H_2O$, and $N_2$ we could assume that the engine was operating at an optimal level. This also implies that if you measure the products of complete combustion ($CO_2$, $H_2O$, and $N_2$ ) and the products of incomplete combustion (CO and O2) that the Air Fuel Ratio or Lambda could be calculated from these measurements. This, in fact, is the case and the FGA 4000 series product offers an option to calculate Lambda from the gas concentrations measured. The equation used by the system to calculate Lambda is discussed in detail in Appendix C.

> ***NOTE:*** *Air-fuel ratios are expressed by weight, not volume. An air-fuel ratio of 12:1 (Lambda .8) is 12 pounds of air mixed with one pound of fuel.*

When a fuel mixture is "lean", there is too much air and too little fuel in the air-fuel ratio. If a mixture is "rich", it has too much fuel and too little air.

Because internal combustion engines are not 100% efficient, even with ideal fuel mixtures, other substances are formed in the combustion chamber during combustion and are exhausted from the engine. The major by-products of "real-world" combustion include:

- Carbon Dioxide ($CO_2$)
- Carbon Monoxide (CO)
- Oxides of Nitrogen ($NO_X$)
- Hydrocarbons (HC)
- Oxygen ($O_2$)

Because the carbon monoxide, oxides of nitrogen and hydrocarbon exhaust products are related to health and environmental concerns, these emissions from automobiles are regulated by federal and state agencies.

**Oxides of Nitrogen (optional)**

Nitrogen makes up about 78% of the air in Earth's atmosphere, and oxygen about 21%. Therefore, about 78% of the air in the combustion chamber is nitrogen. Nitrogen is inert and does not contribute to, or detract from, combustion.

Nitrogen and oxygen only combine with each other to form harmful oxides, including nitric oxide (NO) and nitrogen dioxide ($NO_2$), when both gaseous elements are heated above 1371°C [2500°F].

> ***NOTE:*** *Oxides of nitrogen ($NO_X$) include all the nitrogen compounds formed in an engine's combustion chamber, including nitric oxide (NO) and nitrogen dioxide ($NO_2$). The (x) subscript in place of numbers indicates that all nitrogen/oxygen compounds are included.*

Under some engine conditions, the combustion chamber temperatures easily exceed 1371°C [2500°F], combining oxygen and nitrogen to form $NO_x$.

*Figure 5* ***NOx Vs Lambda***

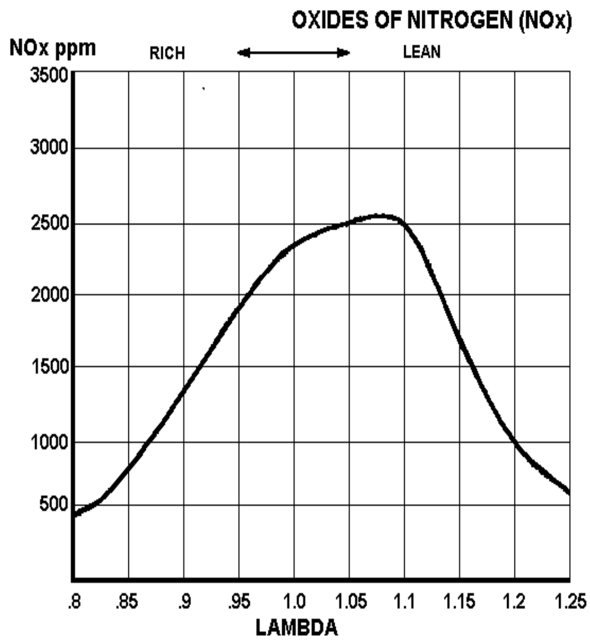



Figure 5 shows the concentration of $NO_X$ in relation to the air-fuel ratio. When based only on air-fuel ratio, combustion chamber temperatures peak at air-fuel ratios of about 18:1 (Lambda 1.25), allowing the formation of $NO_X$. Since modern engines do not normally run at 18:1 (Lambda 1.25), theoretically $NO_X$ emissions should not be a problem.

However, lean air-fuel ratios are not the only cause of NO, emissions. Moderate to heavy engine loads also cause combustion chamber temperatures to increase at ratios much richer than 18:1 (Lambda 1.25).

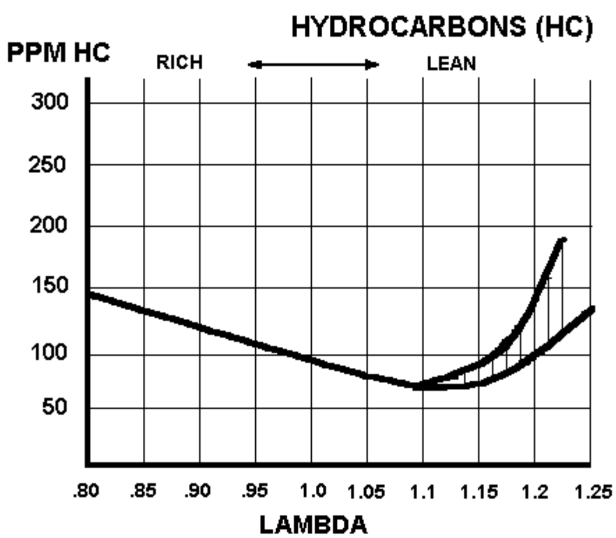
$NO_X$ is not often monitored because:

1. $NO_X$ is normally only formed when the engine is under load. Thus it would be ideal to measure NOx while the vehicle is under load.
2. $NO_X$ does not indicate engine performance or efficiency as does oxygen, hydrocarbons, carbon monoxide and carbon dioxide.

The formation of $NO_X$ does not affect engine performance, but some devices used to prevent it from forming can affect performance and contribute to higher levels of HC and CO if they are not functioning properly.

### Hydrocarbons

*Figure 6* ***HC Vs Lambda***




Hydrocarbons (HC) are organic compounds made up of hydrogen and carbon atoms. The HC present in gasoline engine exhaust is unburned gasoline vapor, and is measured in parts per million (PPM). HC levels in engine exhaust vary with the air-fuel ratio. Figure 6 shows the relationship of HC concentration in exhaust to air-fuel mixture.

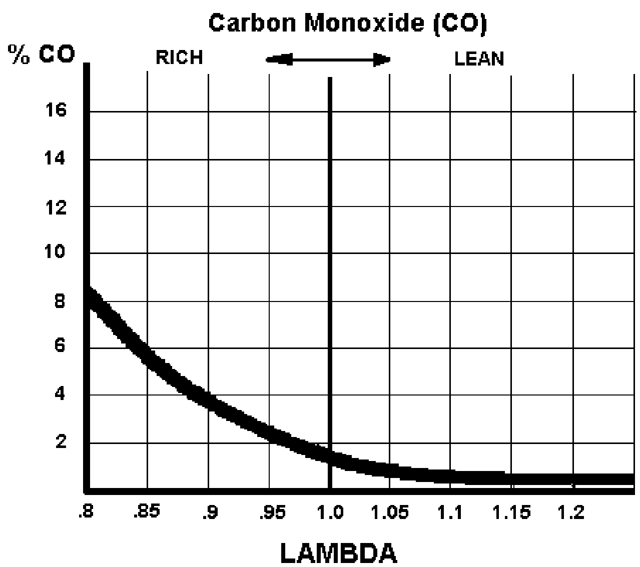
As Figure **6** shows, the lowest HC emissions occur at an air-fuel ratio of about 16.2:1. Since no engine combustion is perfect, some vaporized HC in the combustion chamber is left unburned and exits the engine with the exhaust gases. The amount of HC emissions from the engine depends to a great extent on combustion chamber design.

Also, if the fuel mixture is too lean or rich to support complete combustion, or if ignition does not occur in the combustion chamber at all, HC emissions increase dramatically.

Gasoline evaporating from the carburetor and fuel tank are also sources of HC emissions, known as evaporative emissions.  Vehicles built since 1970 minimize the escape of evaporative emissions.

## Carbon Monoxide

*Figure 7* ***CO Vs Lambda***




Carbon monoxide (CO) is an exhaust byproduct formed when combustion takes place in an engine with less than an ideal volume of oxygen (rich fuel mixture), combining a carbon atom with only one oxygen atom.  The carbon in the combustion chamber comes from the HC fuel, and the oxygen from the inducted air.

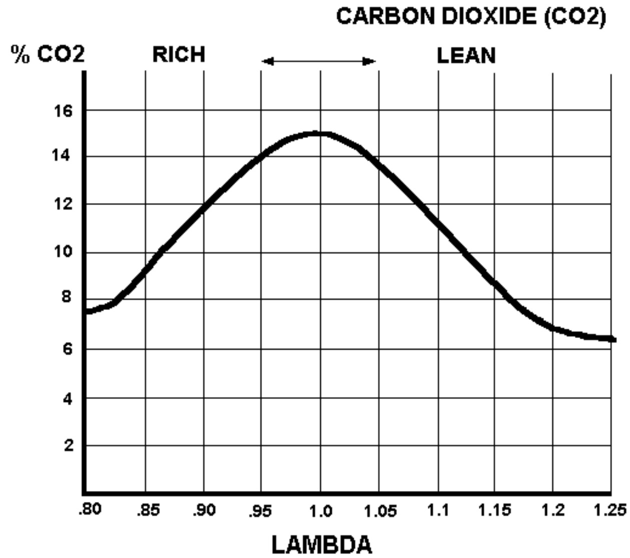
The richer the fuel mixture in the combustion chamber (more HC, less air), the higher the concentration of CO in the exhaust.  Therefore, anything that causes a rich air-fuel ratio results in a high CO content in the exhaust shows the relationship between CO output and air-fuel ratio.

Figure 7 shows that the CO level decreases as the air-fuel ratio approaches about 15:1 (Lambda 1.05), and maintains this low level even while the mixture is further leaned out.  Because of this, CO is a good indicator of fuel mixture richness, but a poor indicator of leanness.

This fact makes the HC and CO content in the exhaust good gauges of engine performance, in addition to their importance for Clean Air Law compliance.  When HC and CO readings are compared with oxygen and carbon dioxide readings, the results can be used to indicate catalytic converter efficiency.

## Carbon Dioxide

*Figure 8* ***CO2 Vs Lambda***



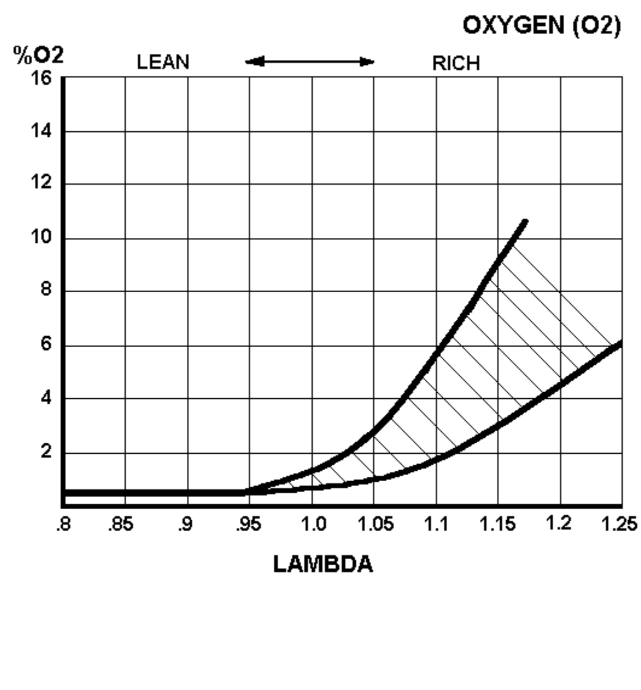

Carbon dioxide ($CO_2$) is a combustion byproduct formed when one carbon atom bonds with two oxygen atoms (an oxygen molecule), and by the oxidation of CO in the catalytic converter. Unlike CO, $CO_2$ is comparatively harmless; animals give off $CO_2$ as a byproduct of respiration.

$CO_2$ is a good indicator of combustion efficiency because its volume in the exhaust peaks at stoichiometric air-fuel ratios. Figure 8 shows the relationship of $CO_2$ to the air-fuel ratio.

$CO_2$ peaks as the combustion chamber fuel mixture approaches about 15:1 (Lambda 1.05), and decreases when the mixture becomes leaner or richer. This fact makes $CO_2$ in the exhaust a good indicator of efficient combustion. $CO_2$ levels can also be used as an indicator of exhaust system integrity.

## Oxygen

*Figure 9* ***O2 Vs Lambda***




The level of oxygen ($O_2$) in exhaust gas is an indicator of air-fuel ratio leanness. The $O_2$ originates in the air the engine inducts and mixes with the HC for combustion. Since the atmosphere is about 21% $O_2$, the percentage of $O_2$ in the exhaust gas after combustion is an indication of air-fuel ratio leanness.

In Figure 9, the $O_2$ concentration is shown to be at a steady low level when the fuel mixture is richer than about 15:1(Lambda 1.05), because all available oxygen is consumed in the combustion process. As the mixture gets leaner, the $O_2$ steadily increases, because less of it is used in combustion. Higher concentrations of $O_2$ in the exhaust are therefore directly proportional to leaner air-fuel ratios.

**Conclusion**

*Figure 10* ***Combustion Products Vs Lambda***

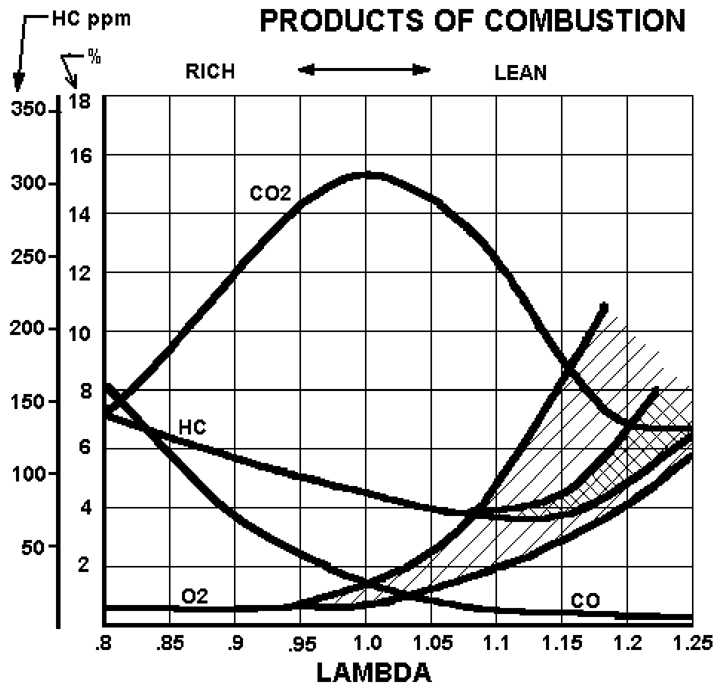



Figure 10 shows the relationship between the air-fuel ratio and the four exhaust gases monitored by the analyzer. It shows:

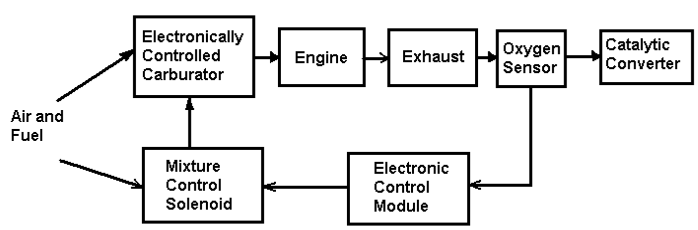
HC levels are lowest when the air-fuel ratio is ideal because most of the fuel is consumed in combustion. Richer or leaner mixtures or ignition problems cause the HC to increase because of incomplete combustion.

1. CO levels are lowest when the air-fuel ratio is nearly ideal because there is less oxygen and carbon left over due to the more-complete combustion occurring at ideal ratios. Richer than ideal mixtures cause CO to increase; leaner has little affect.
2. CO2 levels are highest when air-fuel ratios are close to ideal, and decrease when the mixture becomes richer or leaner.
3. CO levels are near zero when the air-fuel ratio is near ideal because most of it is consumed in combustion. It remains low with richer mixtures, and increases when the mixture leans out.

**Stoichiometric Fuel Mixtures**

As can be seen from Figure , the ideal (stoichiometric) 14.66:1 air-fuel ratio (Lambda 1.0), is near the point where the emission levels drastically change. The stoichiometric air-fuel ratio, where the HC and CO levels are lowest, is as close to perfect combustion as can be attained.

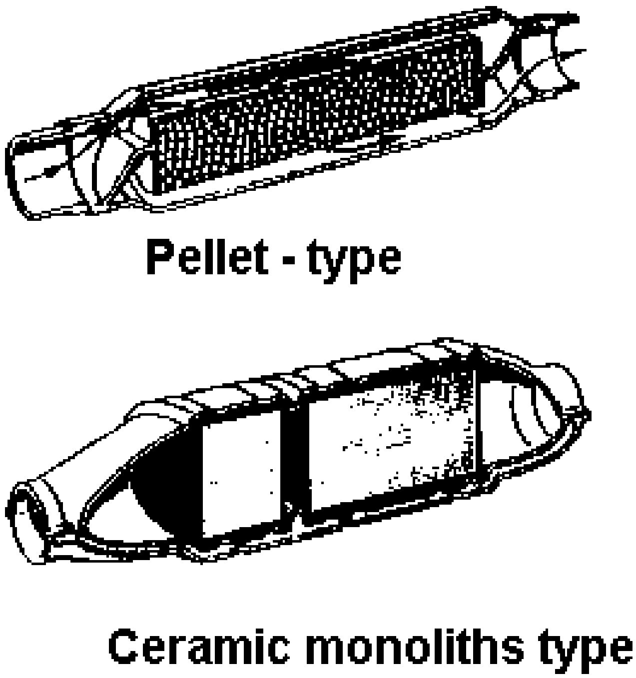
*Figure 11* ***Carbureted Fuel Feedback System***




Combustion temperatures and the air-fuel ratio requirements can change in engines under dynamic load. The only way to ensure that the air-fuel ration remains stoichiometric under most operating conditions is to use a feedback system. So modern engine computers monitor the $O_2$ content of the exhaust gas. The computer calculates the air-fuel ratio, and commands the fuel delivery device, either fuel injector or carburetor, to deliver the amount of fuel required to maintain the correct fuel-air ratio. A typical system is shown in 11.

#### Catalytic Converters

*Figure 12* ***Typical Catalytic Converters***




The first attempt at reducing emission levels in automobiles was to get the air-fuel ratios as close as possible to stoichiometric. However, even engines designed for low emissions, and which are operating properly, may not have HC and CO emission levels low enough to meet Clean Air Standards. Catalytic converters are installed to further reduce emission levels.

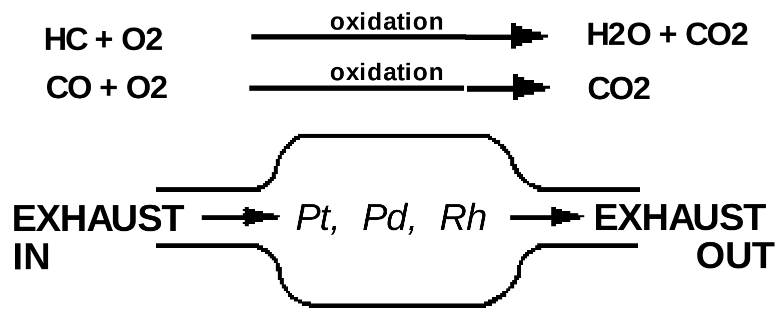
A catalyst is a substance that increases the rate of a chemical reaction without being used up itself The catalytic converters used in automobiles contain a combination of the noble metals platinum, palladium and rhodium. These metals are applied to small beads or to ceramic baffle materials. These materials, called substrates, provide tremendous surface area for exhaust gases to come in contact with the noble metal catalysts. Figure 12 shows the construction of two typical catalytic converters.

In operation, exhaust gases pass into the catalytic converter from the engine, where the gases flow past the catalytic metals. Contact with these metals causes reactions, known as catalytic oxidation, in the exhaust gases, adding $O_2$ to the molecular structure of HC and CO. This turns the HC into $H_2O$ (water) and CO2 (carbon dioxide). The CO is converted to $CO_2$. Figure 13 shows the equations for this process.

Oxidation of any compound requires an abundance of $O_2$. In most cases, engines are equipped with an auxiliary air inlet device, typically called an A.I.R. (Air Injection Reaction) pump or a pulse air system, to inject additional air into the exhaust manifold or catalytic converter, providing the oxygen needed for the reaction (oxidation) to take place. Converters of this type are called oxidation or two-way converters since they only treat two gases.

Figure 13

***HC and CO Oxidation in a Catalytic Converter***




As converter technology has progressed, catalysts have been developed to treat $NO_X$. In this reaction, oxygen is removed from the $NO_X$ compounds, reducing them to nitrogen and oxygen. This is called a reduction reaction. Converters that combine the oxidation of HC and CO with the reduction of $NO_X$ are known as three-way converters. Three-way converters are even more sensitive to air-fuel ratio because their reduction of NO, is only efficient at stoichiometric air-fuel ratios.

Catalytic converters (both two- and three-way types) only lower HC, CO and $NO_X$ by a certain amount. When the engine is operating properly, these emissions are low enough for the converter to decrease them to levels less than specified by state and federal regulations.

### Catalytic Converters and Gas Analysis

Since catalytic converters lower HC and CO producing $CO_2$ and $H_2O$, monitoring HC and CO alone in catalytic converter-equipped vehicles does not give an accurate picture of engine/catalytic converter performance and operating efficiency. The analyzer monitors $O_2$ and $CO_2$ as well as HC and CO, so that all four exhaust products can be compared. This provides a more accurate representation of the operation of the engine and the catalytic converter.

# Appendix B

## Testing

### USING READINGS FOR DIAGNOSIS

This exhaust analyzer is a highly versatile test instrument. In addition to testing carbon monoxide (CO), carbon dioxide ($CO_2$), oxygen ($O_2$), hydrocarbon (HC), and optionally oxides of nitrogen ($NO_x$) for emission control certification requirements or after a tune-up, it can be used to assist in detecting and locating ignition, fuel, exhaust, emission control and engine service problems.

There are a few general facts to keep in mind when using the analyzer:

1. High carbon monoxide (CO) readings usually indicate a fuel mixture richer than ideal. The amount of CO in a vehicle's exhaust is directly related to its air-fuel ratio. High CO levels result from inadequate $O_2$ supply needed for more complete combustion. This is caused by a mixture that is too rich, - too much fuel or not enough air.
2. High hydrocarbon (HC) readings usually indicate excessive unburned fuel caused by lack of ignition or by incomplete combustion. Common causes include a faulty ignition system, vacuum leaks, and fuel mixture problems.
3. High oxygen ($O_2$) readings indicate too lean an air-fuel ratio.
4. Low $O_2$ indicates a rich fuel mixture.
5. High carbon dioxide ($CO_2$) readings indicate a nearly ideal air-fuel ratio and efficient combustion.
6. Low $CO_2$ readings indicate a fuel mixture either too rich or too lean, exhaust system leaks, or analyzer sample dilution.
7. The byproducts of combustion are dependent on the air-fuel ratio.
8. $O_2$ combines with HC to form $CO_2$ and $H_2O$.
9. $O_2$ combines with CO to form $CO_2$.
10. CO is an indicator of richness.
11. HC is an indicator of leanness and misfires.
12. $O_2$ is a better indicator of leanness and misfires than HC.
13. CO and $O_2$ are equal at the stoichiometric air-fuel ratio.
14. $O_2$ and $CO_2$ are indicators of exhaust system integrity, sample hose and probe integrity, or both.
15. $CO_2$ is an indicator of combustion efficiency that peaks at or near the stoichiometric air-fuel ratios, and decreases with lean or rich air-fuel ratio.
16. Air injection systems dilute the exhaust sample with $O_2$.
17. $O_2$ is essential for proper operation of the catalytic converter. Its concentrations are essentially unchanged by the catalytic converter, providing a "window" through the catalytic converter to the engine. $O_2$ levels are higher on vehicles with properly operating air injection systems.
18. If CO goes up, $O_2$ goes down.
19. If $O_2$ goes up, CO goes down.
20. With the air injection system disabled and the CO above 1%, the catalytic converter is oxygen-starved. Without $O_2$, it does not fire, allowing exhaust concentrations to be more like readings taken ahead of the converter.

If readings are within the manufacturer's or local/state/ federal allowable limits, it can generally be assumed that the fuel, ignition, and emission control systems are functioning properly. If they exceed the limits, repairs or adjustments are probably needed.

The chart below lists some of the kinds of problems that could result in abnormal gas readings.

**Legend**
L = low
M = moderate
H = high

| CO | $CO_2$ | HC | $O_2$ | Possible Problem(s) |
|---|---|---|---|---|
| H | L | H | H | Rich mixture with ignition misfire |
| H | L | H | L | Faulty thermostat or coolant sensor. |
| L | L | L | H | Exhaust leak after the converter. |
| L | H | L | H | Injector misfire, catalytic converter operating. |
| H | L | ML | L | Rich mixture. |
| H | H | H | H | Injector misfire, catalytic converter not working; combination of rich mixture and vacuum leak. |
| L | L | H | H | Ignition misfire; lean conditions; vacuum or air leak between airflow sensor and throttle body (false air). |
| L | | H | L | Good combustion efficiency and catalytic converter action. |
| L | | H | L | All systems operating within tolerance; normal reading. |

*Table 1* ***Levels of Combustion Components and Tune-up Problems***

The following table lists some of the results possible when the air-fuel ratio is sustained at conditions ranging from too lean to too rich.

| CONDITION | RESULTS |
|---|---|
| Too Lean | Poor engine power<br>Misfiring at cruising speeds<br>Burned valves<br>Burned pistons<br>Scored cylinders<br>Spark knock or ping |
| Slightly Lean | High gas mileage<br>Low exhaust emissions<br>Reduced engine power<br>Slight tendency to knock or ping |
| Stoichiometric | Best all-around performance |
| Slightly Rich | Maximum engine power<br>Higher emissions<br>Higher fuel consumption<br>Lower tendency to knock or ping |
| Too rich | Poor fuel mileage<br>Misfiring<br>Increased air pollution<br>Oil contamination<br>Black exhaust |

Along with the use of other tools and equipment, the analyzer can be used as a diagnostic tool to help identify that a problem exists. This logical approach, along with other information and knowledge, will lead in a direction that will help to identify the most likely cause of the problem.

### General Tailpipe Testing Tips

1. Read and follow the maintenance and calibration procedures outlined in this manual.
2. Do not test exhaust emissions on vehicles that are smoking excessively or are in obvious need of engine repair. Testing exhaust gas under such conditions may contaminate the sampling system and cause inaccurate readings.
3. Keep the probe tip openings clean and free of debris.
4. Do not place the probe tip in liquids or allow liquids to be drawn into the analyzer's sampling system. If the sampling system is contaminated by any liquids, it will affect the accuracy of any future tests.
5. Do not place the probe in an exhaust pipe until the vehicle is at normal operating temperature. This allows the exhaust system time to burn off any residual moisture.
6. Test engines only when they are at normal operating temperature. Testing with a cold engine does not provide useful test results due to fuel mixture enrichment, and will contaminate the sampling filter quickly, requiring more frequent analyzer service intervals.
7. Never drive a vehicle over the probe, sample hose or power cord.
8. Perform the Leak Test periodically, especially after probe changes and filter service, to ensure accurate analysis.
9. Prolonged use of the analyzer in conjunction with a dynamometer and a hot-running vehicle under load could damage the exhaust probe hose and affect readings.
10. To comply with anti-tampering laws, always follow the manufacturer's specifications when working on emission control devices.
11. Always comply with the governing emission control standards and regulations in your locality when testing exhaust emission levels.
12. Check the manufacturer's specifications and procedures before testing a vehicle.
13. Before testing Tailpipe emission levels, maintain engine speed at about 2000 RPM for 30 seconds, followed by a 30-second normalization period at idle speed before reading gas values.
14. Leaks in the exhaust system will adversely affect readings and should be repaired prior to testing.
15. On vehicles with air injection systems, these systems should be disabled before some diagnostic tests. Denying the system this air results in undiluted gas samples and inhibits catalytic converter operation for more accurate diagnosis.
16. Insert the test probe fully into the tailpipe when testing exhaust emissions to prevent diluted readings.
17. On exhaust systems with twin tailpipes that exit a common resonator or muffler, the exhaust sample can be diluted from outside air entering the tailpipe outlets. To prevent this, block off the pipe not used for the sample probe.

*__NOTE__: Remember to remove the blocking device when testing is complete.*

18. On engines with fuel injection, tailpipe emission readings are only valid at idle speed. Testing at higher engine speeds is only valid when using a dynamometer. However, fuel injected engines should still be conditioned with the engine speed near 2000 RPM as recommended in TESTING TIP #14.
19. On V-type engines with only one oxygen sensor, a misfiring cylinder in one location may have more impact on the $O_2$ sensor than a cylinder in another location.

## VEHICAL INSPECTION

### Exhaust System Integrity

1. Air management system - Ensure that check valves are not leaking.
2. Diverter valve/air switching valve - Ensure that valve is not sticking or leaking into closed off port.
3. Exhaust system pipes and connections - Check that connections are tight and there are no obvious leaks.

### Engine Lamps

Verify that the "Check Engine", "Service Engine Soon", or "Power Loss" lamp is functioning. Ensure that personnel have not removed the bulb.

### Basic Engine other service Functions

Check that engine timing, idle speed, fuel feedback system, vacuum wave form, cylinder time balance bar graph, cranking amps bar graph, etc., are normal for the vehicle being tested.

### Electrical System

Verify alternator operation and battery condition. AC voltage from the alternator can cause improper computer operation and cause miscalculation of fuel delivery and timing.

### Engine Conditioning

Before testing tailpipe emission levels, engines should be at operating temperature.

1. Maintain engine speed at 2000 RPM for 30 seconds.
2. Drop engine speed to idle for 30 seconds.
3. Test the engine.

Some vehicles require special conditioning other than the procedure given here prior to testing idle emission levels. Failure to follow conditioning procedures will usually cause vehicles to fail state tailpipe emission tests even though all systems are operating as designed. For further assistance contact the state emission inspection program administrator.

### Connecting Probe Hose To System

1. Power on the HM5000 according to the instructions in Chapter 2.
2. The analyzer will enter the Warm-up mode immediately. Allow the analyzer to perform a complete Zero cycle. The remaining steps may be completed while the analyzer is zeroing.
3. Connect the exhaust sample hose to the top of the analyzer at the filter/water separator assembly.
4. Wait until the analyzer indicates that it is in STANDBY by displaying its gas values.
5. Insert the probe into the vehicle tailpipe, ensuring that the probe is fully inserted.

> ***NOTE:*** *On vehicles with diffuser screens in the tailpipe, use the optional Anti-Dilution Probe.*

Press the PUMP key.

4. Read the exhaust gas values on the displays.
5. Compare the values shown to:

- All emissions standards.
- The engine manufacturer's specifications.

**Interpretation**

A fuel-injected engine that meets all of the above requirements may still have problems masked by the feedback fuel control system. Consult the vehicle maintenance schedule and perform the recommended service that may be required, including service on emission control devices.

If values exceed specifications and allowances, further diagnostic testing of the engine and exhaust system may be required.

# Appendix C

## Lambda Calculations

**Brettschneider Equation**

In order to calculate the value of Lambda from measurements of combustion by products in the exhaust of a gasoline engine, a mathematical model is necessary. This model must include consideration for the chemical make up of the fuel being burned and many other factors. The model is complicated and the derivation of the equation, beyond the scope of this manual. We will merely site the equation used by the system and the assumptions that were used in implementing it. The equation used in the system is the one derived from a model created by Prof. Brettschneider. It is commonly referred to in the industry as Brettschneider's λ Equation. It is shown below.

$\lambda = A*[B-C]$

Where:

$$A = \frac{21}{21 + 50ux\{(CO/CO2)/(K+[CO/CO2])\}}$$

In the equation for **A** the term "x" is the mass ratio of water in air
even at a relative humidity of 100% this term is very small
As "x" becomes small **A** approaches 1. **A** is assumed to be 1 in the system's calculations.

$$B = \frac{\{CO2+[CO/2]+[NOx/2]+O2\} + \{[Hcv/4]*[K/(K+\{CO/CO2\})]-[Ocv/2]\}*[CO+CO2]}{\{1+[Hcv/4]-[Ocv/2]\}\{CO+CO2+HC\}}$$

In the equation for B: Hcv is the Hydrogen Fraction of the fuel. The default value for Hcv is 1.8
Ocv is the Oxygen Fraction of the fuel. The default value for Ocv is 0 (assume no oxygenated fuels)
K = 3.5 = the water gas constant of combustion

$$C = \frac{\{Wcv/2\}\ \{[CO/CO2]/(K+[CO/CO2])\}\ \{CO+CO2+HC\}}{\{1+[Hcv/4]-[Ocv/2]\}\ \{CO+CO2+HC\}}$$

Where in the equation for C Wcv is the Water Fraction of the fuel.

Because A = 1, the equation for Lambda becomes: $\lambda = B-C$

*Note: Hcv and Ocv affect how the gasoline composition changes the calculation of Lambda. Normal gasoline is only hydrogen and carbon and therefore the default values that the factory puts in for Hcv is 1.8 and for Ocv is 0. However when oxygenates are added to the fuel (as required by law in some locations) these parameters should be changed. The operator can do this in STANDBY mode.*

Appendix

D

## Specifications

The following specifications are subject to change without notice:

**Principal Gases / Ranges Measured**

| | |
|---|---|
| HC, CO, $CO_2$ | Non-Dispersive Infrared (NDIR) |
| $O_2$ and $NO_X$ | ElectroChemical Cell |
| CO, carbon monoxide | Range 0 to 10.00% |
| HC, as n-hexane | Range 0 to 10,000ppm |
| $CO_2$, carbon dioxide | Range 0 to 20% |
| $O_2$, oxygen | Range 0 to 25% |
| $NO_X$, Nitric Oxide (Optional) | Range 0 to 5,000ppm |

HM5000

| | |
|---|---|
| Weight | Less than 2 pounds |
| Size | 7.5” x 3.5” x 2” |
| Display | Backlit LCD, Graphic, 128 x 64 |
| Internal Power | Rechargeable Lithium-Ion Battery Pak |
| External Power | 10-16VDC, less than 1A |
| Operating Temperature | 35° to 110° F |

Output Data Interface

| | |
|---|---|
| Digital | RS-232, eight analog outputs 0-5VDC |
| Altitude | -300m to +1000m [980 ft. to 3300 ft.] |

Probe

| | |
|---|---|
| Material | Pistol grip with Stainless Steel |
| Hose Length | 10’ |
| Requirements | Bar 90/97 |
| Insertion Length | Up to 27” |

# Warranty

## Notice to Buyer and/or user of the analyzer:

Exclusion of warranties and limitation of damages and remedies

This analyzer is warranted against defects in materials and workmanship under normal use and service for one year from the date of delivery to the original purchaser.

The sole obligation of the seller and/or manufacturer under this warranty is limited to repairing or replacing as the seller or manufacturer may elect, free of charge at the place of business of the seller or manufacturer, any parts that prove, in the seller or manufacturers judgment, to be defective in materials or workmanship within one year after delivery to the original purchaser.

This warranty shall not apply and is void if, in the opinion of the seller and/or manufacturer, the portable analyzer or any component thereof has been damaged by accident, other causes not arising out of defects in materials or workmanship.

Before purchasing and using this analyzer, the user should determine the suitability of the product for his or her intended use and, the user assumes all risks and liabilities whatsoever in connection therewith.

If a product malfunction should occur, you may contact the seller or the manufacturer at

Infrared Industries, Inc.
25590 Seaboard Lane
Hayward, Ca. 94545
Voice: 510-782-8100 or 800-344-0321
E-mail: **service@infraredindustries.com**

If it is necessary to return the analyzer, notify the seller in your area or Infrared Industries at the address above. Contact Infrared Industries for an RMA number, which is your authorization to send the unit. Note the RMA number on the outside of the box.  Package the instrument carefully and securely. Do not ship the instrument with accessories. Please include a written description of any observation of the malfunction along with your name, address, and phone number.  Then proceed to ship the instrument with freight prepaid to the address above.

## WARRANTY EXCLUSIONS

*THIS WARRANTY AND THE SELLER AND/OR MANUFACTURER'S OBLIGATION HEREUNDER IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING WITHOUT LIMITATION, THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND ALL OTHER REPRESENTATIONS CONCERNING THE SALE, USE AND/OR PERFORMANCE OF THE ANALYZER.*

*No person is authorized to give any other warranties or to assume any other liability on behalf of the seller or manufacturer. This warranty shall not be extended, altered or varied except by written agreement signed by the seller and the buyer.*

## LIMITATION OF DAMAGES

*IN NO EVENT SHALL THE MANUFACTURER OR SELLER OF THE PORTABLE ANALYZER BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR IN CONNECTION WITH ANY OBLIGATION IMPOSED UPON THE SELLER OR MANUFACTURER IN CONNECTION WITH THIS WARRANTY. SUCH INCIDENTAL AND CONSEQUENTIAL DAMAGES SHALL INCLUDE, WITHOUT LIMITATION, LOSS OF USE, LOSS OF INCOME, LOSS OF PROFIT (INCLUDING LOSSES TO BUSINESS INTERRUPTION), LOSSES SUSTAINED AS THE RESULT OF INJURY (INCLUDING DEATH) TO ANY PERSON, AND LOSS OF OR DAMAGE TO PROPERTY. THE LIABILITY OF THE SELLER AND/OR MANUFACTURER ON THIS WARRANTY IS LIMITED TO ACCEPTING RETURN OF THE PORTABLE ANALYZER, REFUNDING ANY AMOUNT PAID THEREON AND CANCELING ANY BALANCE STILL OWING ON THE EQUIPMENT. THIS REMEDY IS EXCLUSIVE-REPAIR OR REPLACEMENT PROCEDURE*

# Glossary of Terms

This glossary defines terms used throughout the manual.

**Action -** A distinct operation of the analyzer.

**Air-Fuel Ratio (AFR)** – The ratio by volume of air to vaporized fuel in the combustion chamber of an engine. It is usually expressed as the amount of air to one part of fuel. For example the ideal mixture for most fuels is 14.7 parts of air to one part of fuel. This would be written as the ratio 14.7 to 1 or an AFR of 14.7:1. The smaller the quantity of air, the richer the fuel mixture - the larger the quantity of air, the leaner the mixture.

**Cal Gas –** Calibration gas, near full-scale concentration of the gas that the instrument is calibrated to measure, with a nitrogen balance, in a pressurized, certified cylinder.

**Display** –The LCD interface display pannel.

**Lean Mixture -** An air-fuel mixture containing less than the ideal amount of fuel.

**LED** - Light Emitting Diodes used in the displays.

**Indicator –** Small LED that are on the front panel. This device is lit when the analyzer has external power connected.

**Lambda (λ)-** A parameter that expresses air-fuel ratio. Lambda is the ratio of the measured air fuel ration to the ideal or most efficient air fuel ratio as shown below.

$\lambda = \mathbf{AFR}\ \text{measured} / 14.67$

When AFR is displayed as Lambda a value of 1.0 represents the ideal air-fuel mixture of 14.67:1. Values of Lambda greater than 1.0 such as 1.3, represent a lean mixture. Values of Lambda smaller than one, such as 0.85 represent a rich mixture.

**Mode** – An operational state for the system such as warm-up or standby.

**Rich Mixture** -An air-fuel mixture containing more than the ideal amount of fuel.

**Soft Key** – Push buttons that allow the operator to select actions and change the display accordingly.