

**SECTION 2. HARDWARE SPECIFICATIONS****2.1 OVERVIEW**

Section 2 discusses the hardware performance requirements (and design requirements where necessary) for the BAR-97 Emission Inspection System (EIS) needed to perform emissions testing on the vehicles subject to California's I/M program.

This section covers the computer and its peripherals, the emissions analytical train and its sample conditioning system, the dynamometer, the cabinet and its security, bar code scanning, engine speed measurement, and other equipment.

The EIS comprises an ~~IBM compatible~~ personal computer (PC), printer, ~~modem~~TCP/IP connection, software facilitating both two-speed idle and loaded-mode testing, five-gas analyzer with sample system, zero air and calibration gases, dynamometer, dynamometer control interface, engine cooling fan, bar code reader, fuel cap tester, tachometer, OBDII interface, opacity measurement system (optional), and cabinet.

**2.1.1 Computer/Peripheral Compatibility**

~~Computers shall be IBM PC compatible currently available and industry standard. They shall be able to reliably read and/or write IBM compatible 1.44Mb 3.5" diskettes, CDs and DVDs. Systems-Computers~~ must be capable of producing graphic output on monitors and printers. The computer and printer shall be capable of printing graphics and text displayed on the monitor.

~~Systems must be capable of communicating with computers using modems and a dial up connection. The power supply must have the potential to handle at least 100 watts of additional BAR upgrade devices. Personal Computers shall use a current supported version of Microsoft Windows Operating System (OS). When the OS is no longer supported, the OS shall be updated to a newer version. BAR may allow continued use of an unsupported OS at its discretion.~~

PC's shall be able to read and write to Universal Serial Bus (USB), CD or DVD drives within the automotive repair facility environment. The PC shall have 2 unused USB ports.

Systems must be capable of communicating with the VID using TCP/IP connection.

**2.2 GENERAL REQUIREMENTS****2.2.1 Availability of Circuitry**

All components including circuit board and integrated circuits used in the EIS shall be types and brands that are presently in common usage. ~~Custom ROM programs developed~~

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~~by the manufacturer for building the analyzer are allowed.~~ Deviations may be allowed upon approval by BAR.

### 2.2.2 Clock/Calendar

The EIS shall have a real time clock and calendar that shall make available the current date and time. Both time and date shall be in standard ~~IBM-PC~~ format and used to set the computer's date and time on power up.

The EIS shall store the date and time in the *Date of Test*, *Test Start Time* and *Test End Time* fields of the test record and, when appropriate, on the repair record in the *Current Date* and *Current Time* fields.

The communication software shall reset the current EIS date/time settings each time contact is made with the VID except during communication diagnostics. The EIS clock shall be reset to the VID clock at the beginning of each test. If the VID determines that the EIS clock is not keeping correct time, the VID shall set a lockout and a message shall be displayed indicating that service is required.

Resetting the clock after a lockout shall require controlled access available only to the quality assurance contractor (QA), State Representatives and the manufacturer's service technician. The access mechanism or procedures shall be approved by the BAR.

The analyzer clock/calendar shall be equipped with a battery backup feature that has a battery with at least a five-year expectancy. ~~The calendar shall handle the year rollover from 1999 to 2000.~~ All software updates shall be activated by the clock/calendar as directed by the BAR.

### 2.2.3 Data and File Transfer

All calibration, vehicle test records and other EIS files shall be capable of being transferred from the EIS in ~~three~~two ways:

- a) ~~Via By use of an IBM PC compatible modem, [optional: digital subscriber line (DSL), cable modem a TCP/IP connection, wireless, or other similar new technology (located inside the cabinet)] and connection to a telephone line, that allows the EIS to electronically receiving-receive data from and/or transmitting transmit data from-to the VID whenever the EIS connects to the VID.~~
- b) By use of the ~~standard 3.5" IBM 1.44Mb compatible floppy disk~~Universal Serial Bus (USB) Drive on which data is stored.
- e) ~~By means of a standard IBM PC fully compatible DB25 enhanced bi-directional parallel port.~~

### 2.2.4 Capability To Access OBD Fault Codes

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The EIS shall have a port to connect to the OBD II SAE Standardized Link. The link shall enable the EIS to access engine RPM and fault codes for all OBD II equipped vehicles. For certification purposes, BAR requires a description of the OBD II hardware, including its plug and play capability.

Analyzer manufacturers shall incorporate provisions for reading fault codes from vehicles with on-board diagnostics II (OBD II). The CAN protocol is recommended. The SAE Standardized Link shall connect to the vehicle's on-board diagnostics port to automatically interrogate and retrieve fault codes. See section 3 for details.

### 2.2.5 Analyzer Compatibility

The EIS shall be compatible with all types of automotive service operating environments. The analyzer shall operate under the conditions and performance requirements of this specification.

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### 2.2.6 Testing Throughput Capability

The emissions analyzer shall be designed so that it is capable of performing at least 10 tests per hour for eight consecutive hours without experiencing excessive hangup or other deleterious effects.

### 2.2.7 EIS Compatibility and Universal Software

As stated in Section 3.2.3.a, 'If BAR initiates development of a software update, manufacturers shall cooperate with the BAR and/or BAR-approving third party.' If universal software is used, EIS manufacturers shall not make any change in hardware or software that would make the universal software ineffective. This requirement shall include manufacturer submittal of all device drivers for major components and peripherals. The BAR and /or a third party contractor will compile these drivers, communication protocols, and any algorithms, calculations, adjustments, required to facilitate EIS performance per BAR-97 Specification into a Standard Drivers List.

### 2.3 COMPUTERS & PERIPHERAL REQUIREMENTS

The computer system used by a station to control EIS operation, including the computer and peripheral devices such as monitors and printers, shall meet the following requirements:

- a) The computer, including its hardware and software, shall meet industry standards as determined by BAR. The current industry standard shall be considered PCs with hardware using a Microsoft Windows operating system. The EIS manufacturer shall update the operating system as necessary to ensure the computer's operating system is a version supported by Microsoft. The EIS manufacturer shall update the computer's hardware as necessary to function with a currently supported operating system.
- b) The computer shall be able to read and write to Universal Serial Bus (USB), CD or DVD drives within the automotive repair facility environment.
- c) The computer shall have at least two (2) unused USB ports.
- d) The computer shall have one USB Drive. The USB Drive shall be secured within the cabinet tamper protection system. The secured USB Drive shall be designated the State drive.
- e) The computer system shall be capable of producing graphic output on monitors and printers. The computer and printer shall be capable of printing graphics and text displayed on the monitor.
- f) The computer system shall be capable of communicating with the VID using aTCP/IP connection.

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~~An IBM PC compatible computer shall control EIS operation. Each EIS must include the computer system hardware and software shall also be capable of needed to performing all functions required by this specification. The computer shall be capable of~~ the following tasks:

1. Collect, operate on, and record second-by-second readings for HC, CO, CO<sub>2</sub>, O<sub>2</sub>, NO, dynamometer speed and load, and engine RPM.
2. Monitor and control dynamometer functions.
3. Transmit test, calibration, and second by second (at BAR request) records to the VID.
4. Read and interpret bar code labels from DMV registration documents, technician identification cards, testing facility and technician licenses, referee labels and VIN labels, and zero and calibration gas cylinder bar code labels
5. Read data from compact discs (CDs), USB Drives and digital video disks (DVDs).
6. Provide storage for archived test and graphic files.
7. Access engine RPM on OBD II equipped vehicles and interface with OBD and OBD II scan tools.
8. Recall as well as provide vehicle inspection report (VIR) reprint capability for at least 100 emission test records.
9. Interface with an optional partial-flow opacity-measuring device, display and record to the test record.
10. Optionally provide multimedia functionality, with audio/video (AVI) capability for video presentations and teleconferencing, and internal hardware for graphic frame capture.

The BAR reserves the right to add additional programs and functional performance requirements, up to the technical limits of the hardware, to improve the Smog Check program.

Manufacturers may offer analyzers with additional ~~disk~~ drives that can run optional software/hardware application programs; however, the computer shall not be bootable from any additional drive, nor shall any program run from one of these drives have access to the computer's operating system. Programs run from an additional drive shall not be

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capable of interfering with, modifying, corrupting or interrupting any inspection-related program, procedure, or file.

### ~~2.3.1 Minimum Required Microcomputer Configuration~~

~~Computers meeting this specification shall be backward compatible; i.e., be capable of running previous versions of EIS software and hardware.~~

#### ~~a) Operating System~~

~~Each unit must be supplied with an IBM PC compatible, multi-tasking operating system, which provides transmission control protocol / internet protocol (TCP/IP) capability such as OS/2 connect or a MS Windows™ variant. The BAR may approve other systems, which do not initially have full TCP/IP and multi-tasking capabilities if the manufacturer agree to meet the requirements upon the first software update. This upgrade shall be provided at no additional cost to the purchaser.~~

#### ~~b) Processor~~

~~The processor shall be IBM PC compatible. Processing speed shall be equivalent to, or faster than, a computer equipped with a 750 MHz or greater.~~

#### ~~c) Random Access Memory (RAM)~~

~~The system must contain at least 256Mb of user available RAM and must be expandable to at least 512 Mb.~~

#### ~~d) Basic Input Output System (BIOS)~~

~~Upon power up, the system must include a ROM BIOS (basic input/output system) that provides a self diagnostic routine to check the performance of critical PC components (including, at a minimum, the processor, firmware, ROM, hard disk, keyboard, clock, set up RAM and memory), and enable full use of the operating system. The BIOS must fully support all supplied components (an alternative may be approved by the BAR upon request).~~

#### ~~e) Cache Memory~~

~~The processor must use at least 128K cache memory. If more than one processor is used for the central processing, then for each additional processor, 128K more cache memory must be added.~~

#### ~~f) Bus~~

~~When equipped with all BAR specified options, each unit must provide two slots for future expansion, include at least 1 free PCI slot for future expansion. The PCI expansion slot or slots must be fully PCI compliant ("plug and play") and be capable of mapping IRQ 14 & 15. If the video or hard drive interfaces are provided by the motherboard, it shall be capable of being disabled.~~

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### ~~g) Monitors: Display Screen & Drive Trace~~

~~The active screen area must be in color, of .28 dot pitch or less, and measure at least 13" diagonally. The monitor must be capable of noninterlaced resolution up to 1024 X 768 or greater. Power and video connections shall be user accessible without opening the cabinet to allow user replacement of the monitor.~~

~~The display must interface with a color graphics adapter fully compatible with the IBM SVGA color graphics adapter. This interface must be capable of operating in noninterlaced modes up to a resolution of 1024 X 768 or greater while emulating 64K colors or more. The video adapter must be equipped with a 64-bit accelerator chip (or better) to increase its video processing speed and must be PCI bus compliant. The video adapter must be capable of displaying DVD video. The monitor shall be capable of being replaced without opening the EIS cabinet.~~

~~The above specifications do not apply to a second portable monitor that may be provided for the driver. However, this monitor must display all warnings and information required to perform the driving portion of the test (RPM, drive trace, etc.). This second monitor is subject to BAR approval.~~

~~A screen saver shall be provided for the monitor(s).~~

### ~~h) Floppy Disk~~

~~One 1.44Mb floppy drive is required. The floppy drives must have an external door protecting them from contamination (dust). The analyzer's cooling fan (if equipped) shall not create a negative pressure in the case unless the floppy drive(s) are sealed to prevent this negative pressure from drawing dust into the drive. The secured floppy disk shall be designated the "A" drive.~~

### ~~i) Compact Disc (CD)~~

~~Each analyzer sold after this specification release date must be equipped with one CD/DVD drive. The disk drive must be protected from contamination in the shop environment. The CD/DVD drive shall be capable of reading disks that are formatted per ISO 9660 and Universal Disk Format. The CD drive shall be designated the "H" drive. The minimum acceptable sustained transfer rate is 30x for CDs and 2.5x for DVDs and must be multimedia and photo-CD compatible as a minimum. A means for providing security to prevent unauthorized access to lower level system functions shall be submitted by the manufacturer for BAR approval.~~

### ~~j) Hard Disk~~

~~Each unit must come with at least 20 gigabytes of usable formatted uncompressed hard disk storage. The vendor must leave at least 15 gigabytes of usable storage for the BAR and 5 gigabytes of graphic/audio and text storage allotted to the technician. Second by second data, emission inspection data (including graphics)~~

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~~and vehicle data will be stored in the BAR storage area. The system shall warn the technician with a screen prompt when the hard disk is within 10% of being full in any of the allotted storage areas. The hard disk is to be self parking, shock mounted, and able to operate reliably in the expected hostile garage environment. The hard disk must also include a BAR approved method of limiting logical access to BAR data and programs. The hard disk containing the BAR programs and files shall be designated the "D:" drive. The hard drive's minimum acceptable burst transfer (external transfer) shall be 7,000 kilobytes per second. The hard drive's minimum acceptable sustained transfer (internal transfer) shall be 2,000 kilobytes per second. The minimum acceptable average random access time shall be 14ms. No software cache can be used when measuring transfer rate or access times.~~

k) ~~Hard Disk Interface~~

~~The hard disk interface must be PCI bus compliant and use enhanced IDE Mode 4 (ATA-100 or better) or Fast SCSI 2 (or better) or alternative approved by the BAR. The hard disk interface must be capable of maintaining a minimum transfer rate of 8,000 kilobytes per second with all peripherals installed (including options).~~

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**2.3.1 I/O Ports**

~~The unit must include at least one DOS/IBM compatible parallel port. The printer may be connected to this port.~~In addition, the EIS unit must include two baud rate programmable (300 to 115.2K or more) I/O serial ports using BAR CPC female connectors with the following pin outs. One of these ports is for use with an external fuel cap tester (unless the fuel cap test system is provided internally). A second CPC port shall be reserved for a future liquid fuel evaporation tester. Systems may only have 1 external CPC port if the gas cap tester is internal.

The EIS shall include two ~~Universal Serial Bus (USB) version 1.2~~ USB ports for future communication with BAR approved devices. If only one port is available, its expandability into two ports (hub) shall be demonstrated functional. These ports shall be fully installed including all necessary wiring and connections. Ports may be software disabled, but shall not require additional hardware to become active.

All BAR-reserved serial ports (BAR CPC and DB25) shall use 16550 UART chips or better. All I/O ports shall be clearly labeled and easily accessible and may be shared. All BAR CPC pinouts shall be as follows:

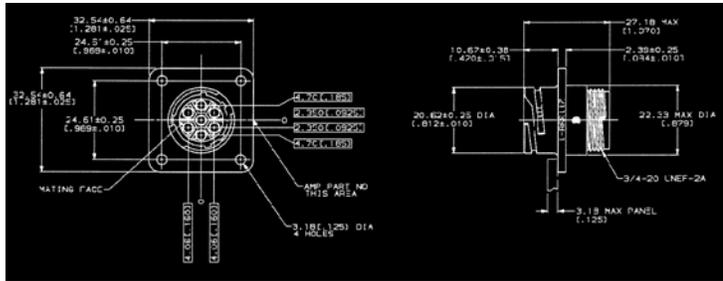
**ANALYZER BAR CPC REVERSE CONNECTOR**

This connector must be compatible with an AMP 211398-1.

<u>PINS</u>	<u>SIGNAL</u>
1	GND
2	+12v
3	RTS.....RESET (request to send)
4	RESERVED (open)
5	SHIELD - GND
6	TXD.....TRANSMIT DATA
7	RCV.....RECEIVE DATA

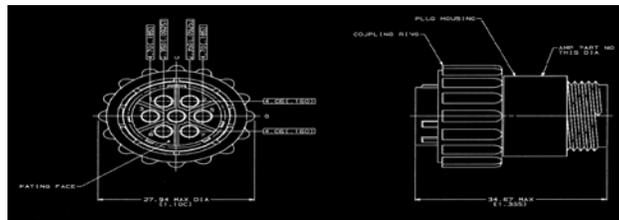
The BAR CPC ports will supply software switchable 12 VDC to equipment attached. The +12V pin must provide circuit protection from shorts, or overload. The circuit protection can be in the form of a fuse, circuit breaker, etc. The circuit protection must be easily accessible to the operating technician for fuse replacement and or circuit breaker reset (unless automatic reset). The circuit must be capable of handling at least 6 watts.

### CPC CONNECTOR DIAGRAM



Square Flange Receptacle

Example of Flanged Receptacle



Example Plug Assembly



Example Plug Assembly

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### 2.3.2 Keyboard and Pointing Device

The EIS keyboard ~~must shall~~ be fully interfaced with the ~~micro~~computer and have all of the necessary normal, numeric, cursor, control, shift, alternate, and function keys needed to operate ~~a~~ an industry standard and currently available IBM-PC-compatible computer. A full-sized keyboard with at least 101 keys should be provided. The keyboard shall be readily available through retail outlets. The keyboard shall be removable and replaceable without requiring access to a secured area within the EIS cabinet. The ~~PC and~~ keyboard must ~~use accept~~ a standard ~~keyboard~~ connector or wireless connection.

~~Provisions-The EIS shall permit the use of for~~ a pointing device, such as a computer mouse must be provided. BAR may approve other pointing devices, such as light pens. If the pointing device requires use of a USB port, such USB port shall not be considered as one of the two USB ports that shall remain unused. If not built in, then a common connector (PS2, DB 9 pin, etc.) must be provided. The device driver must be active and compatible with ~~an MS-a m~~ Mouse or other pointing device. The pointing device must have a sensitivity adjustment available to the technician. ~~BAR may approve other pointing devices, such as light pens.~~

The keyboard and the pointing device shall be capable of being replaced without opening the cabinet.

### ~~2.3.3~~ **Modem**

~~The IBM PC compatible modem, or other similar new technology shall support the following protocol:~~

- ~~▶ Modulation: ITU (International Telecommunications Union, formerly the CCITT) V.22, V.22bis, V.32, V.32bis, V.34.~~
- ~~▶ Error control: ITU V.42, MNP (Microcom Network Protocol) 2, 3 and 4.~~
- ~~▶ Compression: ITU V.42bis, MNP 5.~~
- ~~▶ Connect Time: The modem must be capable of achieving a link with the VID at 56K baud or higher.~~

~~The modems must support at least the following baud rates: 1200, 2400, 4800, 9600, 12k, 14.4k, 19.2k, 21.6k, 24k, 26.4k, 28.8k, 56k asynchronous operation.~~

~~The modem must support the industry standard AT command set.~~

~~If the modem is not using a common expansion bus slot or a common I/O jack (such as a modem that is an integral part of the motherboard), then a means of disabling the modem and an expansion slot or another high~~

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~~speed I/O port must be provided with the intent of supporting an upgraded modem if needed for future expansion.~~

~~If the EIS has performed three complete vehicle inspection tests without one successful communication with the VID out of the six attempts, the modem shall be reinitialized. The EIS manufacturers shall submit their reinitialization methods to the BAR Engineering for approval. Alternative methods for restoring proper modem may be presented by the EIS manufacturer for BAR review.~~

~~The modem lights (if equipped) shall not be visible to the Smog Check technician. The speaker shall remain off at all times and may not be turned on except for manufacturer or BAR diagnostic testing. The manufacturer shall submit a plan for modem diagnostics for approval by the BAR.~~

~~The analyzer shall have a standard, female modular telephone connector located on the back of the analyzer. The telephone cord shall not be attached to the power cord. The telephone line shall be enclosed in a protective cable meeting BAR and UL approval. Alternative methods may be submitted to the BAR for approval.~~

### 2.3.43 **Optional Diagnostic Assistance**

This function shall be offered as an option. When analyzers are submitted to the BAR for certification, this option shall be demonstrated.

Compatibility with H.324 (from International Telecommunications Union's Telecommunication Standardization Sector - ITU-T) and T120 (white boarding) is required. One multifunction device or multiple devices (video capture board, audio board, modem, etc.) may provide this. The EIS must demonstrate ability to perform all functions.

#### a) **Video**

All video components listed in this section shall be capable of meeting the following requirements.

1. Capture images in 65536 colors, at a resolution of 800 x 600 pixels, at a minimum rate of one frame per second and saving the frames to the hard drive in TIFF-LZW format. For certification, one 30 second segment of moving video and 10 still frames.
2. Receive full motion audio/video files and play them when triggered by time, manually or upon request via modem. These files shall be in a format that will run under Microsoft.

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3. Capture still images and provide moving video for teleconferencing. The video teleconferencing system must be capable of displaying at least 10 frames per second, color, at a minimum of 160 x 112-pixel resolution.

Alternative standards may be submitted to BAR for approval.

Two BNC video connectors shall provide the capability of connecting two cameras. The connectors shall be externally accessible.

4. Display DVD video from the DVD drive.

b) **Audio**

A speaker is required on this optional system to provide the ability to play AVI files. This speaker shall also have the capability of providing audio for video teleconferencing or diagnostic assistance.

An external speaker connector is required to provide the ability to connect an external speaker or speakers to this audio system. An industry-standard speaker connector shall be used for the external connector and shall be easily accessible.

If equipped with a handset or headset and internal and/or external speakers, they shall be switchable on and off and shall have volume controls easily accessible to the technician.

An internal microphone may be provided at the manufacturer's discretion. The external microphone connector shall be a common type used for microphones. The audio system shall be capable of H.324 telecommunication. The microphone and handset/headset are not required at this time; however, the connectors and the functionality of the audio system with these components are required and must be demonstrated.

| 2.3.54 **Printer**

The EIS unit shall use a printer capable of printing: at least 4 pages of text per minute, on 8.5" x 11" paper, at 96 characters per line, and 6 lines per inch. This printer will be used to print inspection reports and diagnostic information. The printer must print high-quality graphics at 600dpi or better. Text must be at 300dpi or better. If not continuous feed, the printer must be capable of printing on 8.5" x 14" paper. Printers must have enough memory to print twelve 176 x 144 resolution (1.5" x 1.25") graphic images (pixels) in 64 shades of gray with the remainder of the 8.5 x 14 page filled with text. Page printers (printers that process total pages in memory before printing them) must be expandable to 4Mb of memory. Vehicle inspection reports (VIR) shall be printed for passing and failing vehicle inspections and as duplicates for a passing/failing inspection.

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The printer shall print a VIR duplicating the font and clarity provided in the example VIRs . This is intended to ensure uniformity between manufacturers for style and size.

The printers shall be easily accessible to allow the clearing of paper jams, replacement of paper, ink cartridges, toner, etc. The printer shall be replaceable by the customer with the same make and model.

### | 2.3.65 **Running Changes and Other Hardware Modifications**

Any changes to design characteristics, component specifications and any modifications to the hardware must be approved by BAR. (**NOTE: If software is an integral part of any component, such as the analyzer optical bench, it shall also be subject to the requirements of this section.**) It will be the instrument manufacturer's responsibility to confirm that such changes have no detrimental effect on analyzer performance.

- a) Only BAR-approved hardware configurations and options may be used in BAR-97 analyzers.
- b) All proposed hardware modifications and options must be thoroughly tested before being submitted to BAR.
- c) ALL proposed hardware modifications, including manufacturer-initiated modifications, must be submitted to BAR for testing and approval as follows:
  1. Submit a modified BAR-97 analyzer to BAR Engineering or arrange to update the Engineering test unit.
  2. An application and cover letter containing the following information shall accompany all proposed hardware modifications:
    - i. A description of all of the proposed modifications to be performed (including manufacturer-initiated modifications), a parts list and the installation instructions for the field service representative. Any modifications to the bench or sample system shall also be accompanied with test data and an engineering evaluation regarding the effects of the proposed modifications on the performance and reliability of the analyzer.
    - ii. A timeline showing when the modifications are expected to be performed (start to finish), and how many existing units will be updated.
    - iii. If any special procedures are needed to perform the hardware modifications, describe the procedures for performing the update.

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- iv. If the proposed hardware modifications require changes or additions to the software, documentation for the software update shall be submitted as indicated above.
  - v. Test data showing the EIS meets specification with the modification(s) implemented.
3. Beta Testing- Depending on the type and number of modifications proposed, the bureau may require testing at BAR-approved beta test sites prior to release. The BAR will perform verification tests prior to releasing it for beta testing. See Section 5.12 of this specification for beta testing details.

### 2.4 EXHAUST GAS ANALYSIS EQUIPMENT FOR THE EIS

This section defines the requirements for the equipment needed to determine the concentrations of the exhaust gases of interest during the **BAR-97** loaded-mode and two-speed idle tests. It covers the analyzers/sensors and sampling systems, including sampling probes, hoses, and filters.

#### 2.4.1 General

The analyzer shall be compatible with all types of automotive service operating environments. The analyzer shall operate under the conditions and performance requirements listed below.

#### 2.4.2 Measured Gases

Gases to be measured are hydrocarbons (HC), in parts per million as hexane (ppmh); carbon monoxide (CO), in percent; carbon dioxide (CO<sub>2</sub>), in percent; oxygen (O<sub>2</sub>), in percent; nitric oxide (NO), in ppm. Opacity of diesel exhaust shall be offered as an option.

#### 2.4.3 Types of Analyzers

HC, CO, and CO<sub>2</sub> shall be measured by means of nondispersive infrared (NDIR) analysis. NO shall be measured by means of nondispersive ultraviolet (NDUV), nondispersive infrared (NDIR), chemiluminescent device (CLD), or other device\* meeting requirements in this specification. The EIS manufacturer and the device manufacturer shall cooperate in the development of a satisfactory communication protocol. These protocols shall be shared upon manufacturer and / or BAR request, to allow device interchangeability through standardized communication. All NO-measuring devices, regardless of technology, must have EIS-manufacturer-generated test data showing that they meet the applicable requirements of this specification.

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\* ~~For the purpose of clarification, the electrochemical cells currently in use do not meet this specification. Any technology requires new submittal and certification.~~

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### 2.4.4 Sampling Systems (excluding Opacity)

Sampling systems shall draw exhaust gas from the vehicle under test, shall remove particulate matter and aerosols from the sampled gas, shall drain the condensed water from the sample if necessary, and shall deliver the resultant gas sample to the analyzers/sensors for analysis. The sampling system shall, at a minimum, consist of a tailpipe probe, flexible sample line, a continuously draining water removal system, particulate trap, sample pump and flow control components. The sample system and its components shall be designed to conduct loaded mode testing. This may include the need for active water removal from the sample, e.g., installation of a chiller. Provisions shall be made for the introduction of zero air and calibration gases, as discussed below.

### 2.4.5 Analyzer Requirements

- a) **Automatic Zero:** The analyzer shall conduct an automatic zero adjustment (or equivalent, with BAR approval), prior to each test. The zero adjustment shall include the HC, CO, CO<sub>2</sub> and NO channels. The O<sub>2</sub> channel shall have its span adjusted while the other channels are being zeroed. The analyzer shall perform two steps while zeroing:
  1. **Zero Air:** The analyzer shall be zeroed, and the O<sub>2</sub> sensor spanned, using either bottled or generated zero air. See 'c.3.i for zero air requirements.
  2. **Ambient Air:** Ambient air, filtered for particulates, shall be introduced to the analyzer before the sample pump, but after the sample probe, hose and filter/water trap. The analyzer shall record the concentrations of the five measured gases, but shall make no adjustments.

When the analyzer performs a HC hangup check before the start of an inspection, the recorded ambient air readings shall be subtracted from the sampling readings to determine the amount of HC hangup (residual HC) in the sampling system.

The analyzer shall be locked out from testing until (a) the ambient air has less than 15 ppm HC, 0.02% CO and 25 ppm NO, and (b) until the residual HC obtained through the sample probe is less than 7 ppm.

- b) **Zero Drift Lockout Threshold:** If zero and/or span drift cause the infrared signal levels to move beyond the adjustment range of the analyzer, the operator shall be locked out from testing and instructed to call for service. (The analyzer manufacturer shall indicate, in writing, at what point the drift lockout will occur.)

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- c) **Calibration and Leak Check:** The analyzer shall, to the maximum extent possible, maintain accuracy between gas calibrations taking into account all errors including noise, repeatability, drift, linearity, temperature and barometric pressure.

1. **General:** The analyzer shall automatically require and successfully pass a ~~floppy drive~~ **USB Drive** check, leak check and a gas calibration for HC, CO, CO<sub>2</sub>, O<sub>2</sub> and NO using a method that is approved by the BAR. This must be performed at least every three days or the analyzer shall lock itself out from further I/M tests. The gas calibration shall ensure that accuracy specifications are satisfied or the analyzer shall be automatically prohibited from performing any portion of the I/M test. The gas calibration procedure shall correct the readings to the center of the allowable tolerance range, and shall be within +/- 1.0% of the calibration gas cylinder's label values. When a gas calibration is initiated, the analyzer channels shall actually be adjusted. It is not sufficient to merely check the calibration and do nothing if the analyzer is within allowable tolerances.

The EIS manufacturer shall ensure that the flow rates and fluid pressures through the analyzer benches and sensors stay the same, regardless of whether the source of the flow is the calibration ports or the sample probe. This principle of balanced flow and pressure shall be maintained whether EIS units are equipped with a NO sensor or not. The balance shall be such that low range calibration gas readings, taken on a freshly-calibrated EIS, are within +/-1% or 1 least significant digit of each other when the gas is fed through the calibration port, and then through the sample probe.

2. **Gas Calibration Procedure:** Gas calibration shall be accomplished by introducing gases traceable to the National Institute of Standards and Technology (NIST) into the analyzer either through the calibration port or through the probe. The EIS manufacturers, together with their analyzer / sensor supplier, shall determine which of the following two calibration methods will provide the better and more consistent accuracy for the analyzer / sensor as installed in the EIS.

Single Point - High range calibration gas shall be introduced first, and the analyzer output shall be adjusted to the center of the tolerance range. Low range calibration gas shall then be introduced and the analyzer output automatically checked (not adjusted) to verify that it is within the allowable reading tolerances.

Two-Point - Low range calibration gas shall be introduced first, and the analyzer output shall be adjusted to the center of the tolerance range. High

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range calibration gas shall then be introduced, and the analyzer output shall be adjusted to the center of the tolerance range.

3. Calibration Gases: Calibration span gases and zero air utilized for calibration shall have a  $\pm 2\%$  blend tolerance and a  $\pm 1\%$  certified accuracy, and shall be provided by a BAR-certified gas blender. No more than 2 liters of each gas shall be required to successfully perform a gas calibration; exceptions shall be subject to BAR approval.

The analyzer shall be designed, in a manner approved by the BAR, to accommodate the gas cylinders, air generators and other hardware necessary to perform the three-day gas calibration. Other configurations may be submitted for BAR's consideration. Note that if air generators are used to provide zero air, the resulting oxygen content shall be  $\pm 3\%$  of the nominal value. The analyzer shall be equipped with a gas calibration port. Gas cylinder mounting shall provide adequate room for routine access, servicing and replacement of cylinders, regulators, etc., as well as scanning the cylinder bar code labels. Brackets and other hardware shall be located so that analyzer stability and impact protection are considered in the design. The gas cylinder storage area shall be actively ventilated to prevent gas buildup in case of leakage.

The analyzer manufacturers shall design the connectors used with the gas cylinders so those cylinders containing different concentrations or compositions of gas cannot be switched. As an alternative, manufacturers may use the same connectors on all required cylinders if they display a message instructing the operator to properly connect the hoses to the gas calibration cylinders when they are not connected correctly. In addition for this alternative, some type of reasonably permanent, prominent label or tag shall be used to readily identify which hose should be attached to which cylinder. Other alternatives may be presented to the bureau for consideration. In any event, disposable cylinders shall be equipped with CGA 165 connectors. Jumbo disposable cylinders (zero air only) shall be equipped with CGA 182 connectors. High-pressure cylinders (zero air only) shall be equipped with CGA 590 connectors.

The following calibration gases shall be used:

- i. Zero Air (blend code #37):  
Concentrations: 20.9% O<sub>2</sub>, balance N<sub>2</sub>.  
Impurities: <1 ppm THC, CO, NO; <200 ppm CO<sub>2</sub>.
- ii. Low Range (blend code #32 / without NO #31):  
200 ppm propane

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0.50%	carbon monoxide
6.0%	carbon dioxide
300 ppm	nitric oxide <3 ppm NO <sub>2</sub>
Balance:	oxygen-free nitrogen

iii. High Range (blend code #35 / without NO #34):

3200 ppm	propane
8.00%	carbon monoxide
12.0%	carbon dioxide
3000 ppm	nitric oxide <30 ppm NO <sub>2</sub>
Balance:	oxygen-free nitrogen

BAR-97 EIS units that are not equipped with NO-measurement capability may use tri-blend calibration gases: i.e., gas blends that contain propane, CO, and CO<sub>2</sub> in concentrations as above, but containing no nitric oxide.

4. Zero Air Supply Cylinders & Generators: Zero air may be supplied to the analyzer from either: low-pressure (disposable) cylinders, high-pressure (refillable) cylinders, or zero air generators. Specifications for the cylinders may be found in the gas blender specification.<sup>1</sup> If the EIS manufacturer opts to use a zero air generator (ZAG), it shall meet the following minimum requirements.
- i. Output Air Purity: Generator output air shall meet the purity requirements of c) 3. i., above, when provided with inlet air containing no more than 100 ppm total hydrocarbons as methane, 100 ppm CO, 1,500 ppm CO<sub>2</sub>, and 50 ppm NO<sub>x</sub>.
  - ii. Output Dewpoint: # -40F (# -40°C)
  - iii. Output Particulates: Filtration shall be 99.99% effective at 0.5 micron.
  - iv. Operating Temperature Range: +35°F to +110°F (2°C to 43°C)
  - v. Warm up Time: The zero air generator shall be capable of providing a stabilized supply of air meeting the output purity and dewpoint requirements listed above in less than 30 minutes. During the warm up process, outlet flow from the zero air

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<sup>1</sup>Specifications and Certification Procedures for Calibration and Audit Gases Used in the California Emissions I/M Program. ~~November 1996~~ January 2012.

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generator shall be prevented. In addition, the ZAG shall provide some indication to the operator that it is warming up. The indication might be a lamp or lamp combination on the face of a ZAG that is external to the EIS, or an electrical or electronic signal to the EIS if the ZAG is internal to the EIS. At the completion of a successful warm up, a System Ready indication shall be activated, and outlet airflow permitted.

- vi. Inlet Air: The ZAG shall accept and purify compressed (“shop”) air. The ZAG shall meet the performance requirements of this specification with inlet air pressures ranging from 80 psig to 120 psig as a minimum. If the inlet air pressure falls below the minimum level for proper operation of the ZAG, an indication shall be given and the outlet air flow shut off.
- vii. NO<sub>x</sub> removal: shall be accomplished at a stage in the purification sequence that will minimize the formation of nitric acid, which could corrode the metal and plastic parts. If scrubbing is used, the scrubber shall have a minimum life of one year when challenged with 50 ppm NO<sub>x</sub>. As an option, the ZAG may be supplied with an elapsed time indication to alert the operator that service is necessary.
- viii. HC & CO Removal: HC and CO shall be removed from the air stream by catalytic action. The catalyst shall have a minimum life span of three years. As an option, the ZAG may be supplied with an elapsed time indication to alert the operator that service is necessary. If, at any time, the catalyst temperature falls below that required for HC and CO removal, outlet flow shall be shut off and an indication given. If the temperature should subsequently rise above its minimum operating temperature, e.g., after a power outage, the indication shall automatically be removed and outlet flow resumed.
- ix. CO<sub>2</sub> Removal: CO<sub>2</sub> shall be the last component removed. Removal shall be by means of pressure swing absorption (PSA) technology. If the PSA valve fails, the ZAG’s outlet flow shall be shut off and an indication given.
- x. Pressure Regulator: A pressure regulator inside the ZAG shall provide a fixed outlet pressure specified by the EIS manufacturer.

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- xi. Alternative Configurations: Alternative configurations and removal technologies may be presented to the BAR for consideration.
  - xii. Power Spikes: Externally mounted ZAGs shall have a “Power On” lamp. Power spikes shall not affect the operation of the ZAG.
  - xiii. Mounting: The air generator may be mounted either internally or externally to the EIS cabinet; however, the configuration (1) shall comply with all applicable electrical and safety codes, (2) shall meet applicable Underwriters Laboratories requirements (or BAR-approved equivalent), and (3) shall not cause the response time requirements of ' 2.4.5. r) and 2.4.6 g) to be exceeded. In any event, the separation between an externally mounted zero air generator and the EIS cabinet shall not exceed 25 feet.
  - xiv. Connecting Hose: As a minimum, the hose connecting an externally mounted zero air generator and the EIS cabinet shall meet the analyzer sample hose requirements specified in section 2.4.6.b, shall be capable of withstanding a minimum of 200 psig internal pressure, and shall out gas no more than 10 ppm hydrocarbons between 35F and 110F. Acceptable materials include the following types of new and clean hose or tubing: copper, stainless steel, nylon or nylon core (type 11 / r78), PTFE/FEP (teflon), superthane or polyurethane (polyether based only), synflex 4262.
  - xv. Bar Code Labels: Zero air generators mounted outside the EIS cabinet shall have their bar code labels positioned on an external surface of the generator so that the labels may be conveniently scanned. Zero air generators mounted inside the EIS cabinet shall have their bar code labels mounted on the generator surface that can be scanned if the cabinet is opened. The EIS manufacturer shall mount additional labels (identical to those mounted on the generator) on a surface of the EIS cabinet, so that they may be conveniently scanned by the Smog Check technician.
5. High Pressure Zero Air Cylinder Mounting: Low pressure disposable cylinders may be located in or outside the cabinet. Disposable cylinders located outside the cabinet shall be secured with a bracket. High pressure aluminum cylinders shall be attached to a fixed object (wall, pole, etc.) or if not available may be secured to the EIS cabinet, in such a

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manner as to protect the cylinder's valve and pressure regulator from accidental impact.

6. Cylinder Pressure Regulators
  - i. Pressure regulators shall conform to the requirements of CGA Standard E-4, 3rd Edition (1994) or later.
  - ii. Rated pressure of the regulator shall be equal to or greater than the rated pressure of the cylinder on which it is to be used, corrected to 50°C (122°F). For example, a regulator to be used with a low-pressure disposable cylinder whose fill pressure is 260 psig at 20°C (68°F) must have a rated pressure of  $[(260 + 15) \times (50 + 273) / (20 + 273)] - 15 = 88$  psig, or the next highest standard rating, as a minimum, where 15 as an adder converts psig to psia, and 273 as an adder converts degrees Celsius to degrees Kelvin.
  - iii. Pressure gauges used with the regulators shall conform to all requirements of CGA Standard E-4, (see §5.7).
  - iv. Pressure gauge accuracy shall meet or exceed the requirements of CGA Standard E-4, (see §5.7.3.1).
  - v. Droop/Rise Characteristics: The change in regulator output pressure with decrease in cylinder pressure shall not cause a calibration error of more than ±1% (see §5.4.15). To meet this requirement, EIS manufacturers may use more than one regulator in series, if necessary.
7. Other Requirements: The gas calibration and leak check procedures shall require no more than five minutes. The analyzer shall provide adequate prompts on the display to guide the Smog Check technician through the calibration procedure in a manner that minimizes the amount of gas used. The analyzer shall be designed to keep the loss of calibration gas to an absolute minimum (less than 0.1 liter in 24 hours) if the operator forgets to shut the valve off.
8. Alternate Calibration Frequencies: Proposals for less frequent gas calibrations will be subjected to lengthy accuracy and drift tests. Proposals of this type shall be thoroughly evaluated (e.g., lab as well as field testing in the range of the required span points for accuracy and drift for extended periods of time) and characterized prior to submission to BAR.

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- d) **Propane Equivalency Factor (PEF):** The nominal PEF range shall be between 0.490 and 0.540. For each audit/calibration point, the nominal PEF shall be conveniently displayed for the quality assurance inspectors and the BAR field representatives, in a manner acceptable to the BAR. If an optical bench must be replaced in the field, the manufacturer's Field Service Representative (FSR) shall change any external labels to correspond to the nominal PEF of the new bench. The analyzer shall incorporate an algorithm relating PEF to HC concentration. Corrections shall be made automatically. The corrected PEF value may cover the range of 0.470 to 0.560.
- e) **NDIR/UV Beam Strength:** The beam strength from the source to the detector for all channels shall be monitored such that when the beam degrades beyond the adjustment range of the analyzer, the analyzer shall be locked out from operation. The manufacturer shall specify at what point degradation occurs whereby the signal cannot be corrected.
- f) **Date of Last Gas Calibration:** The date of the last gas calibration shall be kept in non-volatile memory (or on the hard disk) and shall be displayed on the status page. When the system check is adjusted, if the date/time change, positive or negative, is greater than 48 hours, three-day gas calibration/leak check shall be required.
- g) **Lockout Criteria:** If the EIS has not successfully passed a gas calibration and a leak check for a period of three days or more, it shall lock itself out from performing an official I/M test and shall display a message to the operator upon startup.
- h) **Audit Gas Pressure:** During a gas audit, analyzer readings shall not change by more than 1% of the reading if the audit gas pressure is modified by  $\pm 1.5$  PSI from the atmospheric absolute pressure at the probe.
- i) **Audit Gas Blends and Gas Audit Procedure:**  
There shall be four audit gas blends: Low Range, Mid Range #1, Mid Range #2, and High Range. Their concentrations, with  $\pm 2\%$  blend tolerance and  $\pm 1\%$  certified accuracy, shall be as follows:
- i. Zero Air  
Same as zero air calibration gas, except that CO<sub>2</sub> impurity level shall be <1 ppm
  - ii. Low Range  
Same as Low Range calibration gas

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- iii. Mid Range #1
  - 960 ppm propane
  - 2.40% carbon monoxide
  - 3.6% carbon dioxide
  - 900 ppm nitric oxide
  - Balance: oxygen-free nitrogen
  
- iv. Mid Range #2
  - 1920 ppm propane
  - 4.80% carbon monoxide
  - 7.2% carbon dioxide
  - 1800 ppm nitric oxide
  - Balance: oxygen-free nitrogen
  
- v. High Range
  - Same as High Range calibration gas

**NOTE: BAR reserves the right to audit analyzer accuracy using gas blends having component concentrations other than those listed above.**

The audit procedure shall be as follows (see BAR's 'Gas Audit Protocol' for detailed procedure)

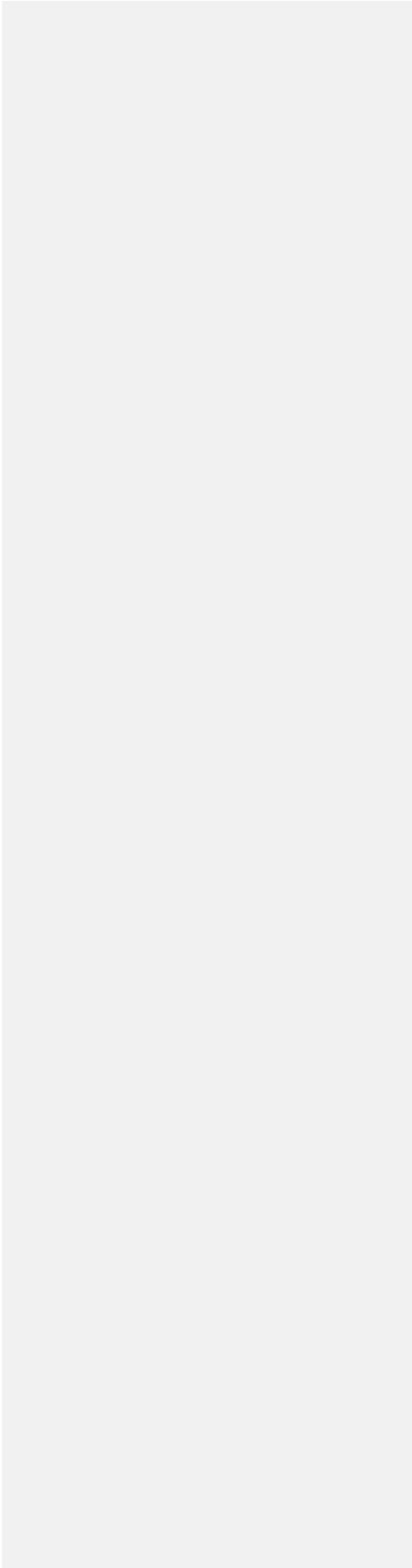
1. Zero the analyzer.
2. Perform a leak check.
3. Enter the State/QA Audit mode or the corresponding field service mode.
4. Flow the Low Range audit gas through the sample probe, ensuring that the pressure at the probe tip is equal to ambient barometric pressure  $\pm 0.1$  in. Hg. (A balloon teed into the gas flow line is an acceptable pressure indicator. It should stand upright, but not inflated.)
5. When the HC, CO, CO<sub>2</sub> and NO readings have stabilized (no less than 60 seconds of gas flow), record them, as well as the PEF value at each audit blend. **(NOTE: The Gas Audit Mode shall present the HC readings in terms of ppm propane, or shall offer the choice of reading in terms of ppm hexane or ppm propane. The auditor shall select and record readings in terms of ppm propane.)**
6. Repeat Steps 4 & 5 for Mid Range #1, Mid Range #2 and High Range audit gases. This sequence of gases must be strictly followed.
7. Repeat Steps 4 and 5 using zero air, and record the stabilized O<sub>2</sub> reading.
8. Compare the readings with the audit gas values. The following relationship shall be used:

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$$A\% = 100 - \frac{(\text{Reading} - \text{Cylinder Value})}{(\text{Cylinder Value})}$$

Where A =  $\pm 4.0\%$  or  $\pm 12$  ppm (parts per million as propane) HC,  
whichever is greater,  
 $\pm 4.0\%$  or  $\pm 0.04\%$  CO, whichever is greater  
 $\pm 4.0\%$  or  $\pm 0.4\%$  CO<sub>2</sub>, whichever is greater  
 $\pm 5.0\%$  or  $\pm 27$  ppm NO, whichever is greater  
 $\pm 5.5\%$  or  $\pm 0.3\%$  O<sub>2</sub>, whichever is greater

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j) *Range and Accuracy:***Emissions Analyzer Range and Accuracy**

Gas	Range	Accuracy (% of point)	Accuracy (absolute)	Range	Accuracy (% of point)	Accuracy (absolute)
HC	0-2000 ppmh	±3%	4 ppmh	2001- 5000 ppmh >5000 ppmh	±5% ±10%	N/A N/A
CO	0 - 10.00%	±3%	0.02% CO	10.01-14.00%	±5%	N/A
CO <sub>2</sub>	0 - 16%	±3%	0.3% CO <sub>2</sub>	16.1 - 18%	±5%	N/A
NO	0 - 4000 ppm	±4%	25 ppm	4001-5000 ppm	±8%	N/A
O <sub>2</sub>	0 - 25%	±5%	0.1% O <sub>2</sub>	-	-	-

Rounding beyond the decimal places shown in the table shall follow the standard mathematical practice of going to next higher number for any numerical value of five or more.

**NOTE: This shall also hold true for pass/fail decisions during an I/M inspection. For example, if 2.00% CO passes but 2.01% CO fails and the reading is 2.0049%, the value shall be rounded down and the decision shall be "Pass;" however, if the reading is 2.0050, the value shall be rounded up and the decision shall be "Fail." Thus, the value displayed and printed on the VIR shall be consistent with the value used for the pass/fail decision.**

k) *Repeatability:***Emissions Analyzer Repeatability**

Gas	Range	Repeatability (% of point)	Repeatability (absolute)	Range	Repeatability (% of point)	Repeatability (absolute)
HC	0-1400 ppmh	±2%	3 ppmh	1400-2000 ppmh	±3%	N/A
CO	0 - 7.00%	±2%	0.02% CO	7.01-10.00%	±3%	N/A
CO <sub>2</sub>	0 - 10%	±2%	0.1% CO <sub>2</sub>	10 - 16%	±3%	N/A
NO	0 - 4000 ppm	±3%	20 ppm	-	-	-
O <sub>2</sub>	0 - 25%	±3%	0.1% O <sub>2</sub>	-	-	-

Accuracy and repeatability shall be defined by the test procedures in Section 5.

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l) **Noise:**

**Emissions Analyzer Noise**

Gas	Range	Noise (% of point)	Noise (absolute)	Range	Noise (% of point)	Noise (absolute)
HC	0-1400 ppmh	±0.8%	2 ppmh	1400-2000 ppmh	±1%	N/A
CO	0 - 7.00%	±0.8%	0.01% CO	7.01-10.00%	1±%	N/A
CO <sub>2</sub>	0 – 10%	±0.8%	0.1% CO <sub>2</sub>	10 – 16%	1±%	N/A
NO	0 – 4000 ppm	±1%	10 ppm	-	-	-
O <sub>2</sub>	0 – 25%	±1.5%	0.1% O <sub>2</sub>	-	-	-

Noise shall be defined operationally as follows: Sample Mid Range #1 Audit Gas for 20 seconds. Collect all the analyzer output readings for each channel over the 20 seconds. (For example, if the analyzer outputs are read by the EIS at the rate of twice per second, the total number of readings would be 40.) The peak-to-peak noise shall be calculated as:

$$NOISE = \frac{\sqrt{\sum (X_i - \bar{x})^2}}{n}$$

Where  $x_i$  = the  $i^{th}$  reading of the set of readings  
 $\bar{x}$  = the arithmetic average of the set of readings  
 $n$  = the total number of readings

The noise, as calculated above, shall be within the limits specified in the table above, AND, in the set of data collected, no more than 5% of the readings in the set shall deviate (peak-to-peak) from the average by more than 150% of the specified limits.

m) **Minimum Analyzer Display Resolution:** The analyzer electronics shall have sufficient resolution and accuracy to achieve the following:

HC	1 ppm	HC
CO	0.01%	CO
CO <sub>2</sub>	0.1%	CO <sub>2</sub>
NO	1 ppm	NO
O <sub>2</sub> (optional)	0.1%	O <sub>2</sub>
RPM	1 mph	RPM
Speed	0.1 mph	
Load	0.1 hp	

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- n) **Display Refresh Rate:** Dynamic information being displayed shall be refreshed at a minimum of twice per second. Alternatives may be submitted to the BAR for its approval.
- o) **Interference Effects:** The interference effects from non-interest gases shall not exceed  $\pm 4$  ppm for HC,  $\pm 0.02\%$  for CO,  $\pm 0.20\%$  for CO<sub>2</sub>, or  $\pm 20$  ppm for NO. Corrections for collision-broadening effects of combined high CO and CO<sub>2</sub> concentrations shall be taken into account in developing the factory calibration curves, and is included in the accuracy specifications. Interference gases shall be as follows:

<u>Interference Gases</u>	
16%	Carbon Dioxide in Nitrogen
1600 ppm	Hexane in Nitrogen
10%	Carbon Monoxide in Nitrogen
3000 ppm	Nitric Oxide in Nitrogen
75 ppm	Hydrogen Sulfide in Nitrogen
75 ppm	Sulfur Dioxide in Nitrogen
28 ppm each	Benzene, Xylene, Toluene in Nitrogen (NDUV only)
18%	Carbon Dioxide <u>and</u> 9% Carbon Monoxide in Nitrogen Water-Saturated Hot Air

**NOTE:** Interference gases shall have a  $\pm 2\%$  blend tolerance and  $\pm 2\%$  certified accuracy.

- p) **Warm-up Time:** The analyzer shall reach stability within 30 minutes at 35°F from startup. If an analyzer does not achieve stability within the allotted time frame, it shall be locked out from I/M testing and a message shall be displayed instructing the operator to call for service.
- q) **System Lockout During Warm-up:** Functional operation of the gas sampling unit shall remain disabled through a system lockout until the instrument meets stability and warm-up requirements. The instrument shall be considered "warmed-up" when internal analyzer verifications are complete and the zero readings for HC, CO, CO<sub>2</sub>, O<sub>2</sub> and NO have stabilized, within the allowable accuracy values, for five minutes without adjustment.
- r) **Analyzer/Sensor Response Times**  
Analyzer/sensor response times are defined as follows:
  1. **Rise time:** When a gas is introduced to a sensor's sample cell inlet or inlet port, the time required by the sensors output to rise from first indication of response to the input gas ( $t_0$ ) to a given percentage of the final stable reading of a gas concentration. Two rise times are specified:

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- i.  $T_{90}$ : The time required to reach 90% of the final gas concentration reading from first indication of response to the input gas.
  - ii.  $T_{95}$ : The time required to reach 95% of the final gas concentration reading from first indication of response to the input gas.
2. **Fall Time:** When a gas is removed from a sensor's sample cell inlet or inlet port, the time required by the sensor's output to fall from first indication of withdrawal of the gas ( $t_S$ ) to a given percentage of the final stable reading of a gas's concentration. Two fall times are specified:
- i.  $T_{10}$ : The time required to fall to 10% of the stable gas concentration reading from first indication of withdrawal of the gas.
  - ii.  $T_5$ : The time required to fall to 5% of the stable gas concentration reading from first indication of withdrawal of the gas.

### **Analyzer/Sensor Response Time Requirements**

	HC, CO, CO2	NO
$T_{90}$	3.5	4.5
$T_{95}$	4.5	5.5
$T_{10}$	3.7	4.7
$T_5$	4.7	5.7

The differences between  $T_{90}$  and  $T_{10}$  and between  $T_{95}$  and  $T_5$  shall be no greater than 0.3 seconds.

Only the  $T_{90}$  and  $T_{10}$  times shall be measured and recorded during 3-day calibrations.

Note that the oxygen ( $O_2$ ) sensor's response time is specified as an overall system response time (see '2.4.6.g) in harmony with the generally accepted European specifications.

During a three-day calibration, the EIS measures the  $T_{90}$  and  $T_{10}$  response times of the CO,  $O_2$ , and NO channels. If a channel exceeds its maximum allowable response time by one second (see table above), a warning shall be displayed; exceeding two-seconds shall cause the

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**EIS to fail calibration. From the above table, absolute maximum failing response times for T<sub>90</sub> are 5.5 seconds (CO) and 6.5 seconds (NO); and for T<sub>10</sub> are 5.7 seconds (CO) and 6.7 seconds (NO). For O<sub>2</sub>, the corresponding T<sub>90</sub> and T<sub>10</sub> times are 7.5 seconds and 8.5 seconds, respectively.**

**NO readings shall be time aligned based on last calibration time. For example a new sensor that starts out with a 2 second T90 response time then degrades to a 3.2 second T90 response time, as measured during calibration, shall result in an additional time offset of 1.2 seconds.**

- s) ***HC Hangup***  
The HC hangup shall be 7 ppm or less before the EIS permits an I/M test to begin.
- t) ***Emissions Accounting/Accuracy***  
The manufacturer shall ensure that its analytical system provides an accurate accounting of the actual exhaust emissions produced during the test, taking into consideration the individual channel accuracies, repeatabilities, interference effects, sample transport times and analyzer response times.

### 2.4.6 Sampling System Components

- a) ***General:*** The system shall be designed to ensure durable, leak-free operation and shall be easily maintained.

The sampling system shall be designed to withstand typical vehicle exhaust temperatures when the vehicle is driven through the ASM5015 test cycle for 120 seconds.

Materials that are in contact with the gases sampled shall not contaminate or change the character of the gases to be analyzed. The sampling system shall be designed to resist corrosion and material degradation for at least five years.

The system shall be designed to ensure durable, leak-free operation and easy maintenance.

- b) ***Sample Hose:*** The sample hose shall be 25 ft ±0.5 ft in length, when measured from the front of the EIS cabinet. On the main sample hose, the dual exhaust quick connect fitting shall be located at least 7 feet back from the probe. The auxiliary hose shall be equal in length to the distance from the dual exhaust quick connect to the probe on the main hose. Other configurations may be submitted to BAR for its consideration

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The hose material in contact with the exhaust sample shall be nonporous and not subject to out gassing; it shall not absorb, adsorb, react with, or affect the sample in any manner. The outer coating of the hose shall be abrasion-resistant and unaffected by the substances found in a typical service facilities environment.

The sample hose shall be flexible, yet shall resist kinking and crushing, as defined in Section 5.

The sample hose shall be connected to the probe and to the analyzer sample system with screw-type fittings.

- c) **Sample Hose and Probe:** The sample hose and probe shall withstand exhaust gas temperatures at the probe tip of up to 1100°F for five (5) minutes.
- d) **Sample Probe:** The analyzer manufacturer shall equip the analyzer with a sampling probe, which meets the following criteria:
  - 1. **Retention** - The probe shall incorporate a positive means of retention to prevent it from slipping out of the tailpipe when in use.
  - 2. **Hand Grip** - A thermally-insulated, securely-attached hand grip shall be provided on the probe in such a manner that easy probe insertion using one hand is insured.
  - 3. **Flexibility** - Manufacturers shall supply two types of removable probe tips with each analyzer sold. The probe and both probe tips shall meet the following criteria:
    - i. the probe shall be designed so that the tip extends 16 inches into the tailpipe;
    - ii. the probe and probe tip should be designed so the average garage operator can easily remove and reinstall them without special tools;
    - iii. a handle, made of thermally insulating materials, shall be attached to a rigid, reasonably non-crushable portion of tubing made of stainless steel or something equivalent, which can be easily removed from the sample line and reinstalled by the operator; and
    - iv. the probe tip shall be shielded so that debris is not scooped up by the probe when it is inserted into the tailpipe.
    - v. In addition, one of the probe tips supplied with the analyzer shall be of the traditional style meeting the following specifications:

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- a. flexible enough to extend into a 1½-inch diameter exhaust pipe having a three-inch radius, 45-degree bend; and
  - b. the flexible portion shall be constructed so that it is sealed to prevent any sample dilution.
- vi. Manufacturers shall also supply the analyzer with an essentially straight probe tip (no more than a 15° bend) meeting the following specifications:
- a. made of stainless steel, 3/16 inch outside diameter (O.D.) solid-wall tubing, which is readily available;
  - b. designed so that the connector between the removable probe tip and the rigid portion of tubing is up inside the tailpipe at least three inches to reduce the effects of any leak that might occur: and
  - c. the probe tip shall be shielded so that debris is not scooped up by the probe when it is inserted into the tailpipe.
4. Serviceability - For the purposes of economical replacement, the flexible portion of the probe assembly shall be designed so it can be replaced. The probes supplied shall be readily available.
5. Materials - The probe shall be made of materials that will withstand exhaust temperatures up to 1100°F. Use of dissimilar metals with thermal expansion factors of more than five percent shall not be used in either the construction of probes or connectors.
6. Audit Gas Introduction - Probes shall be designed to allow, or shall be supplied with an adaptor allowing, the introduction of audit gas from a one-half inch inside diameter flexible hose. The probe tip or the adaptor shall be sized to provide a tight fit so that dilution cannot occur at the probe/hose connection.
7. Probe Cap - A probe tip cap suitable for performing a system leak check shall be provided if the vacuum decay method of leak check is utilized. The cap shall be permanently attached/tethered to the EIS. Otherwise, whatever hoses and connectors are necessary shall be provided to allow the operator to perform the leak check.
- e) ***Particulate Filter and Water Trap***
1. The particulate filter shall be capable of trapping at least 97% of all particulates and aerosols 5 microns or larger.

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2. The filter element shall not absorb or adsorb hydrocarbons.
  3. The water trap shall be sized to remove exhaust sample water from vehicles that are undergoing a loaded-mode test and that are fueled with gasoline, gasohol, propane, compressed natural gas (CNG), as well as with alternative and oxygenated fuels, such as methanol (M85), ethanol (E85), and reformulated gasolines with MTBE as the oxygenate. The filter element, bowl and housing shall be inert to these fuels as well as to the exhaust gases from vehicles burning these fuels. The condensed water shall be continuously drained from the water trap's bowl. Sufficient water shall be trapped, regardless of fuel, to prevent condensation in the sample system or in the optical bench's sample cell over the full range of ambient operating conditions (see §2.4.7, §2.4.8, and §2.4.12, while testing a vehicle under loaded-mode conditions. Consideration shall be given to incorporating active water removal, such as integration of a chiller, to remove the excess moisture generated in vehicle exhaust during a loaded-mode test.
  4. All sample system filters shall meet BAR-97 Specification and meet or exceed EIS Manufacturer specifications. In the event BAR in-house aftermarket filter test procedures are deemed insufficient to quantify filter performance per OEM specifications by either EIS Manufacturer or Aftermarket parts supplier, the aftermarket parts supplier shall submit the OEM and aftermarket filters to an independent laboratory (not the same filter manufacturer) for comparison testing. Upon BAR review of independent lab test procedures and results BAR may issue approval.
- f) **System Leak Check:** The analyzer shall require that a leak check be successfully passed on the same frequency as the gas calibration.
- The analyzer shall not allow an error of more than 1% of reading using High Range BAR-97 span gas to perform the leak check.
- g) **System Response Time Requirements for Analyzer Channels:**  
The overall system response time of the analytical train comprises the Transport Time and the Analyzer/Sensor Response Time (see ' 2.4.5 r).
1. **Transport Time:** The time from the exhaust sample's entry into the tip of the sample probe until the analyzer/sensor first begins to respond to the sample. The Transport Time shall be no more than 5 seconds for HC, CO and CO<sub>2</sub> and no more than 7.5 seconds for NO and O<sub>2</sub>.
  2. **System Response Time:**

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- i. HC, CO, & CO<sub>2</sub> Channels: The response rise time (see ' 2.4.5.r1) from the probe to the display shall be no more than eight (8) seconds to T<sub>90</sub>. In addition, the response fall time shall be no greater than 8.3 seconds to T<sub>10</sub>.
  - ii. NO Channel: The response rise time (see ' 2.4.5 r) i) from the probe to the display shall be no more than 12 seconds to T<sub>90</sub>. In addition, the response fall time shall be no greater than 12.4 seconds to T<sub>10</sub>.
  - iii. O<sub>2</sub> Channel: The response rise time shall be no greater than 15 seconds to T<sub>90</sub>. The response fall time for a step change in concentration from 20.9% O<sub>2</sub> to 0.1% O<sub>2</sub> shall be not greater than 40 seconds.
- h) **Hangup Check (Ref. §2.4.5 s)**  
Activation of the emission measurement mode of the EIS shall be prevented unless a successful hangup check has been performed immediately prior to the test sequence. Hangup shall not exceed 7 ppm hexane prior to testing. A unit with a clean sample system shall have a HC hangup time of no more than 120 seconds. If the HC hangup does not drop below 7 ppm within 150 seconds, the following message shall be displayed: "**POSSIBLE DIRTY FILTERS OR SAMPLE LINE.**"
- i) **Dilution**  
The analyzer supplier shall demonstrate to the satisfaction of the BAR that the flow rate on the EIS unit shall not cause more than 2% dilution during sampling of the exhaust of a 1.6L engine at normal idle. Two-percent dilution is defined as a sample of 98% exhaust and 2% ambient air.

### 2.4.7 Temperature Operating Range

The analyzer, including all of the software/hardware enclosed in the cabinet, shall operate within the performance specifications described herein in ambient air temperatures ranging from 35° to 110°F. Analyzers shall be designed so that adequate airflow is provided around critical components to prevent overheating (and automatic shutdown) and to prevent the condensation of water vapor, which could reduce the reliability and durability of the analyzer.

### 2.4.8 Humidity Operating Range

The analyzer, including all of the software/hardware enclosed in the cabinet, shall operate within the performance specifications described herein at up to 90% relative humidity throughout the required temperature range.

### 2.4.9 Opacity

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An opacity option shall be offered for use in testing light and medium-duty diesel-powered vehicles. It shall be a partial-flow device, meeting the performance requirements of ISO 11614, and shall interface seamlessly with the analyzer software via an RS232C port. A DB25 pin serial port or other BAR-approved connector is required. Adjustments such as electronic signal filtering shall be incorporated so as to correlate with other opacity-measuring devices and standards. Other methods of measuring opacity may be submitted for BAR consideration. The devices shall be calibrated by a method and at a frequency approved by BAR.

### 2.4.10 Humidity

Relative humidity shall be measured prior to the start of every inspection in order to calculate Kh, the nitric oxide humidity correction factor. The humidity measurement device shall have the following minimum characteristics:

Relative Humidity Range:	5% - 95%
Sensor Accuracy:	±3% of full scale or better
Operating Temperature Range:	35°F - 110°F

The relative humidity reading shall be recorded in the *Relative Humidity* field of the test record.

### 2.4.11 Ambient Temperature Measurement

Ambient temperature shall be measured prior to the start of every inspection, and shall be recorded in the *Ambient Temperature* field of the test record. The temperature-measuring device shall have the following minimum characteristics:

Range:	0 - 140°F
Accuracy:	±3°F or better

### 2.4.12 Barometric Pressure Compensation

Barometric pressure shall be measured prior to the start of every inspection, and shall be recorded in the *Barometric Pressure* field of the test record. The barometric measuring device shall have the following minimum characteristics:

Range:	24 - 32 in. Hg absolute
Accuracy:	±3% of point or better
Operating Temperature Range:	35°F - 110°F

### 2.4.13 Dynamometer Interface

The dynamometer (or controller if applicable) shall use a BAR-approved connector. The connector (or a separate connector) shall reserve one wire at the dynamometer (or controller if applicable) that shall provide software switchable (on/off) +12V with .5AMP circuit protection to each +12V line. The communications protocol, approved by BAR, shall be made available, upon request, to BAR-approved dynamometer manufacturers.

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The necessary hardware and software connectivity details shall be sufficient to allow a seamless interface to the system that meets all of the requirements of the specification.

### 2.5 ASM DYNAMOMETER AND AUXILIARY EQUIPMENT SPECIFICATIONS

#### 2.5.1 Dynamometer Identification

All dynamometers shall have an identification plate permanently affixed showing, as a minimum: the dynamometer manufacturer's name, the system provider's name (i.e., provider who obtained the BAR certification and who markets the system using the dyno), production date, model number, serial number, dynamometer type, maximum axle weight, maximum HP absorbed, roll diameter, roll width, base inertia weight, and electrical requirements (including voltage and amperage).

#### 2.5.2 Two-Wheel Drive Vehicle Dynamometer

The dynamometer and any ramps required for above ground dynamometer use shall accommodate all two-wheel drive light-duty vehicles up to 6,000 lbs. axle weight (unloaded), except for those vehicles equipped with antilock braking systems (ABS) or traction control (TC) which require an all wheel drive (AWD) dyno.

#### 2.5.3 All-Wheel-Drive (AWD) Dynamometers

The dynamometer shall accommodate vehicles with axle weight 6,000 lbs. or less (unloaded) having wheelbases from 85 to 125 inches as a minimum. AWD dynamometers shall insure the application of correct vehicle loading, and shall not damage the four-wheel-drive system of the vehicle. These dynamometers shall be capable of properly testing vehicles equipped with ABS and TC systems.

#### 2.5.4 Power Absorption

##### 2.5.4.1 Acceptable Configurations

Power absorption methods shall be described in the manufacturer's certification submittal package. All configurations are subject to BAR approval.

##### 2.5.4.2 Power Absorber Range

The range of the power absorber unit (PAU) shall be sufficient to simulate the load required to perform an ASM5015 test and an ASM2525 test on any vehicle in its weight range. For the ASM5015, the vehicle loading is 50% of the maximum loading required for that vehicle during the Federal Test Procedure (FTP) test; for the ASM2525, the vehicle loading is 25% of the maximum loading required for that vehicle during the FTP test. All dynamometers shall be capable of performing these tests for any vehicle in its weight range. The power absorber shall be able to absorb, at 14 mph and above, a minimum of 25 horsepower continuously for a steady state test lasting at least five minutes, with three minutes between tests for at least 10 consecutive tests.

##### 2.5.4.3 Power Absorption Unit (PAU) Accuracy

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The power absorber shall be adjustable in 0.1 hp increments and the accuracy of the system (PAU + Parasitic Losses) shall be  $\pm 0.25$  horsepower or  $\pm 2.0\%$  of required loading for dynamometer certification, whichever is greater, in either direction of rotation. (For field auditing the accuracy shall be  $\pm 0.5$  horsepower or 4% of the required loading.)

**2.5.4.4 Vehicle Loading**

The vehicle loading used during the ASM driving cycles shall follow the equation:

$$\text{THP} = \text{IHP} + \text{PLHP} + \text{GTRL}$$

Where:

- THP = Total horsepower (tire losses and parasitics) for an ASM test.
- IHP = Indicated Horsepower value set on the dynamometer.
- PLHP = Parasitic Loss Horsepower due to internal dyno friction.
- GTRL = Generic Tire/Roll interface horsepower losses at speed, based on primary drive axle weight measured at or before the dyno. Axle weight shall be  $\pm 100$  lbs. of actual over a range of 800 - 6000 lbs. and shall record the weight on test record. For passenger cars for which test weights are not available, the actual weight shall be used. Unless otherwise noted, any horsepower displayed during testing shall be THP.

**2.5.5 Inertia****2.5.5.1 Base Inertia**

The dynamometer shall be equipped with a mechanical flywheel(s), or with full inertia simulation providing a total base inertia weight of 2000 lbs.  $\pm 40$  lbs. Any deviation from the 2000 pounds base inertia shall be quantified and the coast-down time shall be corrected accordingly. The actual inertia weight  $\pm 10$  lbs. shall be marked on the dynamometer ID plate or on the flywheel.

**2.5.5.2 Inertia/Inertia Simulation**

The dynamometer, as delivered, shall be capable of conducting, at a minimum, diagnostic level transient inertia simulations with an acceleration rate between 0 to 3.3 mph/sec with a minimum load (power) of 25 hp at 14 mph over the inertia weight range of 2,000 to 6,000 lbs. For the diagnostic level inertia simulation, the 25-hp criterion is a requirement on acceleration only, while for the full inertia simulation option, the requirement is for both acceleration and deceleration. Mechanical inertia simulation shall be provided in 500 lb. minimum increments; electric inertia simulation shall be provided in one (1) lb. increments. Any deviation from the stated inertia shall be quantified and the inertia simulation shall be corrected accordingly. Mechanical or electrical inertia simulation, or a combination of both, may be used, subject to review and approval by the BAR.

**a) Diagnostic Level Simulation**

1. System Response - The torque response to a step change shall be at least 90% of the command value within 300 milliseconds.
2. Inertia Simulation Error - An inertia simulation error (ISE) shall be continuously calculated any time the actual dynamometer speed is

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between 5 and 60 mph. The ISE shall be calculated using the equation below and shall be within 3% of the inertia weight selected (IWS) for the vehicle under diagnostics testing when driving a predetermined drive trace. When driving a non-predetermined drive trace, the ISE shall be within 5% of the IWS. If, after the first 5 seconds of the test mode the ISE exceeds this tolerance for more than 3 consecutive seconds, the test mode timer shall be set back to 5 seconds. Should this happen a second time, the test shall be invalid.

$$ISE = [(IWS - It) / IWS] \times 100$$

$$It = I_m + (1/V) \int_0^t (F_m - F_{rl}) dt$$

Where:

ISE = Inertia Simulation Error in percent.

IWS = Inertia Weight Selected.

It = Total inertia being simulated by the dynamometer.

I<sub>m</sub> = Base mechanical inertia of the dynamometer.

V = Measured roll speed.

F<sub>m</sub> = Force measured by the load cell.

F<sub>rl</sub> = Road load force required by IHP at the measured roll speed.

t = Time.

3. Maximum Vehicle Speed - The dynamometer shall be designed to accommodate a vehicle speed of up to 60 mph.

### 2.5.6 Rolls

#### 2.5.6.1 Size and Type

- a) *Main Rolls (2WD Dynamometers)*: The dynamometer shall be equipped with twin rolls. The rolls shall be electrically or mechanically coupled side-to-side and front-to-rear. The dynamometer roll diameter shall be between 8.5 and 21.0 inches. Other configurations will be considered by BAR. The spacing between roll centers shall be determined by the following equation. The actual spacing shall be within +0.5 and -0.25 inches of the calculated value.

$$\text{Roll Spacing} = (24.375 + D) \times \sin 31.52^\circ$$

Where D = Roll Diameter

Roll spacing and roll diameter expressed in inches.

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Alternative roll spacing may be approved by BAR.

- b) *Roll Speed:* Roll speed and roll counter shall be accurate within 0.1 mph for speeds up to 60 mph. The side-to-side (split) rolls shall maintain speed synchronization of  $\pm 0.2$  mph.
- c) *Track Width:* The dynamometer shall have a usable track width of at least 100 inches. The dynamometer rolls shall have a minimum width of 96 inches and the space between the split rolls shall not exceed 30 inches. Tire overhang, the distance from the end of the roll to the tire bulge when the tire is in the widest position, shall not exceed 2 inches. If, during vehicle stabilization, the tire attempts to push outside the usable width, tire/vehicle damage shall be prevented. Tire damage includes, but is not limited to, excessive scrubbing either against the dynamometer or the restraints. The dynamometer shall not damage any part of the vehicle during testing, ingress or egress under normal operation.
- d) *Roll Characteristics:* The roll size, surface finish, and hardness shall be such that tire slippage is minimized, that water removal is maximized, that the specified accuracy of distance and speed measurements are maintained, and that tire wear and noise are minimized.
- e) *AWD Dynamometers:*
  - 1. Auxiliary Rolls - The auxiliary rolls for AWD and traction control vehicles shall be cradle rolls complying with the provisions of ' 2.5.6.1a) above or a single roll.
  - 2. Front-to-Rear or Side-to-Side Synchronization - Front-and rear-wheel or side-to-side (split) rolls shall maintain speed synchronization of  $\pm 0.2$  mph.

### 2.5.7 Dynamometer Calibration

The dynamometer shall be automatically calibrated. Calibration procedures shall be approved by BAR.

#### 2.5.7.1 Accuracy Over Operating Ambient Temperature Range

The dynamometer's accuracy, when warmed up, shall not deviate by more than  $\pm 0.5$  hp over any temperature variation within the full ambient operating temperature range of 35°F to 110°F. This may be accomplished by intrinsic design or by software correction techniques.

At any constant temperature, the dynamometer shall have an accuracy of  $\pm 0.5$  hp within 15 seconds of the start of the test, and shall have an accuracy of  $\pm 0.25$  hp within 30 seconds of the start of the test.

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The dyno manufacturer shall demonstrate that its dyno horsepower deviation between cold and warmed-up operation is less than 0.25 hp within an ambient temperature range of 35°F - 110°F. For temperatures outside the specified range, the dyno shall provide correction or proceed with a manufacturer-recommended warm-up sequence until full warm-up condition has been reached.

Alternative means of compensating for cold vs. warm operation may be approved by BAR.

### 2.5.7.2 Coast-Down Check

Each dynamometer's calibration shall be checked every 72 hours by means of an automated dynamometer coast-down check procedure approved by BAR. An integral motor, while recommended, is not required. The coast-down performance check shall be conducted between the speeds of 30-20 mph and 20-10 mph. All rotating dynamometer components shall be included in the coast-down check. If either the measured 30-20 mph coast-down time or 20-10 mph coast-down time is outside the window bounded by Calculated Coast-Down Time (CCDT) (seconds)  $\pm 7\%$ , then it shall be locked out for official inspection purposes until recalibration allows a passing value.

- a) Randomly select an IHP2525 value between 8.0 hp and 18.0 hp and set dynamometer PAU to this value. Coast down the dynamometer from 30 to 20 mph.

$$CCDT_{@ 25 \text{ mph}, yy} = \frac{\left( \frac{0.5 \times DIW}{32.2} \right) \times (V_{30}^2 - V_{20}^2)}{550 \times (IHP_{2525, yy} + PLHP_{25, yy})}$$

Where:

DIW	=	Dynamometer Inertia Weight (total inertia weight of all rotating components in the dynamometer)
$V_{30}$	=	Velocity in feet/sec at 30 mph
$V_{20}$	=	Velocity in feet/sec at 20 mph
$IHP_{2525, yy}$	=	ASM2525 indicated horsepower, randomly selected during each coast-n check
$PLHP_{25, yy}$	=	Parasitic horsepower for specific dyno at 25 mph.
yy	=	Placeholder for dyno roll diameter

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- b) Randomly select an IHP5015 value between 8.0 hp and 18.0 hp and set dynamometer PAU to this value. Coast down the dynamometer from 20 - 10 mph.

$$CCDT_{@ 15\text{ mph, yy}} = \frac{\left(\frac{0.5 \times DIW}{32.2}\right) \times (V_{20}^2 - V_{10}^2)}{550 \times (IHP\ 5015_{yy} + PLHP\ 15_{yy})}$$

Where:

DIW	=	Dynamometer Inertia Weight (total inertia weight of all rotating components in the dynamometer)
V <sub>20</sub>	=	Velocity in feet/sec at 20 mph
V <sub>10</sub>	=	Velocity in feet/sec at 10 mph
IHP5015 <sub>yy</sub>	=	Randomly selected ASM5015 indicated horsepower
PLHP15 <sub>yy</sub>	=	Parasitic horsepower for specific dyno at 15 mph.
yy	=	Placeholder for dyno roll diameter

All-wheel drive dynamometers capable of disengaging the auxiliary rolls shall perform coast-downs in both the two and four-wheel drive modes at least once every 15 days on the rear rolls, or alternative approved by BAR.

2.5.7.3 Parasitic Losses

If the dynamometer is unable to pass the coast-down check, the dynamometer's parasitic loss horsepower (PLHP) shall be determined at 25 and 15 mph.

- a) Calculate the PLHP of the dynamometer at 25 and 15 mph by coasting the dynamometer down with IHP set to zero from 30 - 20 mph and 20 - 10 mph, using the equations below.

1. Parasitic losses at 25 mph

$$PLHP = ((1/2)(DIW/32.2)(V_{30}^2 - V_{20}^2)) / (550 \times CCDT)$$

Where:

PLHP	=	Parasitic loss horsepower
DIW	=	Dynamometer Inertia Weight. Total inertia weight of rotating components in pounds.
V <sub>30</sub>	=	Velocity in feet per second at 30 mph.

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- V<sub>20</sub> = Velocity in feet per second at 20 mph.
- ACDT = Actual coast-down time required for dynamometer to coast from 30 - 20 mph.

2. Parasitic losses at 15 mph

$$PLHP = ((1/2)(DIW/32.2)(V_{20}^2 - V_{10}^2)) / (550 \times ACDT)$$

Where:

- PLHP = Parasitic loss horsepower
- DIW = Dynamometer Inertia Weight. Total inertia weight of rotating components in pounds.
- V<sub>20</sub> = Velocity in feet per second at 20 mph.
- V<sub>10</sub> = Velocity in feet per second at 10 mph.
- ACDT = Actual coast-down time required for dynamometer to coast from 20 - 10 mph.

2.5.8 Other Requirements

2.5.8.1 Vehicle Restraint

The EIS shall be equipped with a means or device for restraining front-wheel-drive vehicles under test. Its primary function shall be to limit the vehicle's side-to-side movement on the dynamometer rolls. This means or device shall be engaged when the test is ready to be performed and shall be disengaged after the test has been completed. The restraint system shall be designed to minimize vertical and horizontal force on the drive wheels so that emission levels are not significantly affected. The restraint system shall allow unobstructed vehicle ingress and egress and shall be capable of safely restraining the vehicle under all reasonable operating conditions. The EIS shall not allow a test to be initiated unless the restraint system is in place. Restraints may also be provided for rear-wheel-drive vehicles, but if not, rear-wheel-drive vehicles shall have their front wheels securely chocked.

Vehicles on four-wheel drive dynamometers shall be restrained sufficiently to prevent forward/reverse movement in addition to side-to-side movement while minimizing the effects on vehicle emissions.

2.5.8.2 Installation

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Vehicles shall be approximately level (not to exceed  $\pm 5^\circ$  degrees) while being tested on the dynamometer. Dynamometers may be installed in-floor or above-ground, as long as this requirement is met.

### 2.5.8.3 Load Measuring Device

If the dynamometer fails a coast-down check or requires a recalibration for any other reason, the load measuring device shall be checked using a dead-weight method (or BAR-approved equivalent), and shall cover at least three points over the range of loads used for vehicle testing. Dead weights shall be traceable to National Institute of Standards and Technology (NIST), and shall be accurate to within  $\pm 0.5\%$ . The dynamometer shall provide automatic load measuring device calibration/verification feature.

The same dead weight (or BAR approved equivalent) shall be used for axle weight scale calibration. Upon new dyno installation or any dynamometer service, the axle weight scale shall be recalibrated with the dynamometer PAU calibration dead weight. Mechanical advantage (leverage) may be used to achieve greater loads than the actual dead weight mass.

### 2.5.8.4 Wheelbase Selection

The wheelbase spacing of an all-wheel drive dynamometer shall be adjustable to accommodate vehicles having a wheelbase between 85 and 125 inches. The system shall provide a locking mechanism to secure the dynamometer at the desired wheelbase.

### 2.5.8.5 Automatic Lift

Dynamometers shall have an automatic lift between the rolls to allow smooth vehicle transition onto and off the rolls. Alternative methods of effecting this transition may be submitted to BAR for its approval.

### 2.5.8.6 Driver's Aid

The EIS shall be equipped with a driver's aid that shall be clearly visible to the driver during the loaded-mode test. The aid shall continuously display the required speed, the number of seconds into the test mode, driver's actual speed/time performance (a display showing deviation between set point and actual drive trace), engine rpm, and necessary prompts and alerts. The driver's aid shall also be capable of displaying test and equipment status and other messages as required.

### 2.5.8.7 Driver's Remote Control Device

Each EIS shall be equipped with a means of allowing the driver to start the test, perform an emergency stop, and perform other necessary and convenient functions related to the test, while inside the vehicle.

### 2.5.8.8 Fan

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A fan shall be provided for cooling the engine of the vehicle under test. It shall be mobile to position in front of the vehicle. The fan blades shall have a maximum diameter of 30 inches. The rotational axis of the fan shall be at least 16 inches above the shop floor, and no greater than 35 inches above the floor. The fan must provide at least 3000 cubic feet per minute (cfm) of air speed at all speed settings. If the fan blade diameter is less than 20 inches, the fan must be adjustable by rotating the fan housing, or by raising and lowering the fan housing. The adjustment positions of the fan must not allow the catalyst to be cooled abnormally.

### 2.5.8.9 Augmented Braking

During ASM testing, augmented braking shall consist of applying 500 lbs. of braking at the roll surface, wherever possible given the limitations of the PAU. If, during an ASM test, the correct applied load for a given vehicle exceeds the 500 lbs., the PAU shall maintain the correct vehicle load until the rolls come to a stop (i.e. the load will not drop 500lbs. but maintain the heavier loading). The 500 lbs. of braking is made up of tire losses, dynamometer parasitic losses, and PAU load.

### 2.5.8.10 Safety Provisions

The dynamometer shall provide a means of facilitating the removal of the vehicle in case of system failure or power outage.

### 2.5.8.11 Dynamometer Controller

The dynamometer controller may be a separate unit or included in the analyzer cabinet. Regardless, the dynamometer controller and its inputs, outputs and functionality shall not vary over the operating temperature range, and shall be unaffected by AC voltage variations of  $\pm 10\%$  or less, EMI/RFI, and shall be resistant to shock and vibration.

## 2.6 CABINET & PERIPHERAL REQUIREMENTS

All cabinets, including modifications are subject to BAR approval and shall be tamper resistant as specified in section 1.4.

~~2.6.1 Power/Telephone Cord The modem shall be designed to connect to the EIS by means of a modular telephone connector with a standard wiring configuration. The connector shall be located on the back of the analyzer cabinet. Alternatives to this requirement to improve the durability of the connection interface and the telephone line are encouraged and may be proposed by the manufacturer for evaluation by the BAR. The telephone cord shall not be attached to the power cord. The telephone line shall be enclosed in a protective cable meeting BAR and UL approval. Alternative methods to protect the telephone line may be submitted to the BAR for approval.~~

~~The manufacturer shall include provisions to ensure that the power necessary to activate the modem at the appropriate time is available.~~

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The analyzer shall be supplied with a 25-foot UL-approved power cord. The manufacturer shall design the cabinet so that convenient storage is provided for the excess cord not needed to reach the nearest power outlet.

### 2.6.2 Power Requirements

The EIS shall operate only on alternating current (AC). No direct current (DC) models will be acceptable. The EIS shall not be powered by a portable AC generating unit. The manufacturer may seek an exception to this rule if it can be shown, to the satisfaction of the BAR that the analyzer is immune to the line frequency variations of the portable AC generating unit. Immunity to line frequency variations is defined here as line frequency variations which will not cause more than one percent of full scale (FS) disturbances on any of the analyzers. Additionally, any AC portable generating unit used with the EIS shall not have frequency excursions exceeding one hertz from 60 hertz.

Input power shall be 115 VAC, 60 hertz. All instruments shall meet the specified requirements over an input voltage variation of at least  $\pm 12$  volts. Maximum allowable performance change due to line voltage variations shall not exceed one-third of the accuracy requirements.

### 2.6.3 Instrument Construction

The instrument shall be designed and constructed to provide reliable and accurate service in the automotive repair environment. The analyzer shall be supplied with a cabinet that is equipped with a storage area large enough to secure all accessories and operating manuals

#### a) Materials

The materials used in instrument construction shall be resistant to corrosive type substances found in the automotive repair environment and be designed to last for at least the period of the warranty.

#### b) Finish

The exterior and interior finish of the entire cabinet and console shall be sufficiently durable to withstand the chemicals and environmental conditions normally encountered in the automotive repair environment for the period of the warranty.

#### c) Mobility

The analyzer may be a permanently mounted or mobile with wheel cabinet. Wheels shall be at least five inches in diameter and have a locking mechanism capable of preventing movement on a 15° incline.

If mobile, the analyzer shall be designed so that movement over rough surfaces (three-inch deep holes) and on 15° incline will not cause it to tip over. Analyzers shall not tip over when placed at the center of an inclined plane that makes an

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angle of 10 degrees with the horizontal and rotated 360° stopping in the position where it is most likely to tip over. In addition, the analyzer shall not become unstable or tip over when rolled straight off the edge of a two-inch high platform or when one wheel is rolled over a drain, two inches below the surface, inside an 18-inch diameter depression.

d) **Identification**

The analyzer serial number, the date of production, the EIS number and the PEF shall be conveniently displayed to the quality assurance inspectors and the BAR field representatives, in a manner meeting the BAR's approval. The first two characters of the EIS number shall be alphas denoting the manufacturer's initials, and shall not be changeable from the keyboard even in the manufacturer's service mode. The initials chosen are subject to approval by the BAR to prevent duplication between manufacturers. The remaining six characters shall be numeric. The numbers shall be right justified. Zeroes shall be used to fill any blank spaces between the initials and the numerics. For example, the EIS number for analyzer #23 from Hobo Electronics would be "**HE000023**."

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- e) **Electrical Design**  
Provisions shall be made for storing the power cord in a manner satisfactory to the BAR. Fuses or circuit breakers shall be used to protect individual electrical circuits and emission analyzers. Main circuit breakers and fuses shall be readily accessible from the exterior of the cabinet. Analyzer operation shall be unaffected by electrical line noise and voltage surges. The analyzer shall be sufficiently protected from voltage surges to prevent damage to the analyzer from the simultaneous start up of a 220-volt compressor, an arc welder, hydraulic controls and other equipment commonly found in the typical automotive test and/or repair environment.
- f) **Electromagnetic Isolation and Interference**  
Electromagnetic signals found in an automotive environment shall not cause malfunctions or changes in accuracy in the electronics of the EIS. The instrument design shall insure that readings do not vary as a result of electromagnetic radiation and induction devices normally found in the automotive garage environment (including high energy vehicle ignition systems, RF transmission radiation sources and building electrical systems).
- In addition, the manufacturer shall ensure that the analyzer processor and memory components are sufficiently protected to prevent the loss of programs and test records.
- g) **Vibration and Shock Protection**  
System operation shall be unaffected by the vibration and shock encountered under the normal operating conditions encountered in an automotive environment. Instruments, motors, pumps, and disk drives shall be shock-mounted to absorb any vibration that might affect the system operation.
- h) **Instruction Manual & Accessories Storage**  
A drawer and/or enclosed cabinet with shelves shall be provided to store the analyzer operating instruction manual, the BAR Smog Check Manual (expected to consist of two two-inch loose leaf binders), the BAR Repair Manual (expected to consist of the equivalent of one two-inch binder), and EIS accessories.

### 2.7 BAR CODE SCANNER

A non-contact bar code scanner capable of reading both code 39 and 128 symbologies and all necessary interface software and hardware designed to read labels meeting SAE specifications J1877 and J1892 is required on all analyzers \*\*. The bar code scanner shall

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\*\*The bar code scanner shall be of standard, "off-the-shelf" technology approved by BAR.

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be able to autodiscriminate between the symbologies. The bar code scanner shall be capable of reading a VIN through a windshield. The bar code scanner shall be capable of reading a DMV bar code having a maximum length of 7¼" (seven and one quarter inches). The bar code scanner shall be capable of reading a calibration gas bar code having a maximum length of 4 inches on a surface with a maximum radius of curvature of 6⅝ inches.

In addition to collecting information from the VIN label, scanners may also be required to enter emission application information from the BAR recognized abbreviated lookup manuals.

The BAR recommends that the manufacturers contact the vehicle manufacturers and BAR-certified gas blenders to inquire about obtaining bar-coded labels for testing purposes.

### 2.7.1 Minimum Required Configuration for Bar Code Scanner

The analyzer shall be equipped with a standard port configuration and standard connector ~~(such as DB9 or DB25 RS232C external connector)~~ for the bar code scanner. Scanner and communication must be BAR approved (proprietary scanner systems will not be permitted). The bar code scanner will be used to load emission control system information from application manuals and from the permanent bar code labels placed on the vehicle by the manufacturer. The supplied bar code scanner shall come with at least a twenty (20) foot long self coiling cord and be able to read bar codes placed on the door frames and under the hoods. Manufacturers will be expected to include any software necessary to utilize the data gathered from labels.

### 2.8 FUEL CAP TESTER

The EIS shall include a fuel cap testing system meeting the following specifications. The fuel cap tester may be provided separately but must provide the serial communication described below.

- a) The fuel cap tester shall test the leak rate of fuel caps to prevent evaporative emissions.
- b) The tester shall be designed so that tethered caps can be accommodated without moving the EIS and shall be capable of pressurizing the fuel cap for this test. The pressurizing system shall apply a controlled pressure of 30 inches of H<sub>2</sub>O to the fuel cap. The system shall indicate a fail if the leak rate is greater than 60cc per minute. The system shall indicate a pass if the leak rate is 60cc or less per minute. The leak test shall last no longer than 20 seconds.
- c) The tester shall have the capability to change the leak rate pass/fail setpoint if needed at a later date.

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- d) The system shall be tamper resistant.
- e) Fuel cap test equipment shall indicate a pass/fail condition.
- f) The tester shall have an indicator and/or screen prompt informing the technician when the system is ready to test (pressurized and power turned on).
- g) The tester shall have a means of controlling the maximum reservoir pressure and relieving overpressure.
- h) If the tester is battery operated, it must be equipped with an automatic shut-off and a low-battery indicator.
- i) Data Transmission (for External Cap Tester Only)  
The tester shall be equipped with a serial data port and shall transmit pass/fail and calibration information to the EIS database via the data link.
  - 1. **BAR-97 Communication Data Link**  
The fuel cap tester shall communicate with the EIS to record information such as pass/fail, calibration, etc. Communication and power to the unit shall be provided by one cable (if the unit is external). A BAR CPC serial port as shown below, shall be used for communication and to provide the power needed to operate the fuel cap tester. Other methods of providing power and communication may be submitted to BAR for approval.
  - 2. The connector on the EIS and pin outs shall be as follows:

**ANALYZER BAR CPC REVERSE CONNECTOR**

This connector must be compatible with an AMP 211398-1 connector. The BAR CPC ports will supply software switchable 12V DC to equipment attached. The 12V pin shall be protected for power surges over .5 AMPS. The circuit protection shall be easily accessible to the technician unless it is an automatic reset system. The pin-out shall be as follows:

<u>PINS</u>	<u>SIGNAL</u>
1	GND
2	+12v
3	RTS.....RESET (request to send)
4	RESERVED (open)
5	SHIELD - GND
6	TXD.....TRANSMIT DATA
7	RCV.....RECEIVE DATA

## SECTION 2

The power for the tester will be provided via the BAR CPC connector as shown above.

NOTE: No serial interface cable shall exceed 35 feet unless it has been demonstrated to the BAR Engineering Unit that sufficient shielding has been provided to prevent radio frequency interference (RFI).

3. Communication protocol will be provided by the BAR on a need-to-know basis.

### j) Calibration and Accuracy

1. Each system will have a calibrated, screened orifice PASS/FAIL MASTER cap set. The set shall be individually calibrated; the calibration shall be traceable to the NIST. The master cap set shall consist of a PASS MASTER flowing 52 to 56cc per minute and a FAIL MASTER flowing 64 to 68cc per minute (both measured at 30 in. H<sub>2</sub>O pressure). The tester shall be checked every three days with the master calibration caps. The calibration caps shall be calibrated before initial usage and on an annual basis unless quality control tracking suggest less frequent intervals are appropriate. The calibration method shall be NIST traceable. Equipment out of calibration may not be used.
2. The tester accuracy shall be  $\pm 3$ cc per minute and shall be capable of maintaining its accuracy from 35° to 110°F and at elevations from -60 to 7,000 feet.

### k) Adapters

1. The system shall be capable of testing at least 95% of the California motor vehicle fleet from model year 1976 up to and including model year 1995 year (excluding pressurized fuel systems such as CNG, LPG, etc.) that are equipped with evaporative control systems.
- ~~2. Adapters shall be made available within two years of the introduction of new model year vehicles.~~
3. Adapter set shall have a means of indicating which vehicles they fit.

### 2.9 ENGINE RPM DETECTION

The analyzer shall utilize a tachometer capable of detecting engine RPM with a 0.5 second response time and an accuracy of  $\pm 3\%$  of the true RPM. Prompts may be provided to assist the technician in locating a RPM signal on vehicles equipped with DIS.

## SECTION 2

Based on the vehicle identification information entered by the technician, the analyzer shall advise the technician regarding which vehicles require a primary pick up, which require that an alternate counting algorithm be used and which require the use of an auxiliary piece of equipment. Analyzers shall be provided with all the software and hardware that is necessary to make them capable of reading engine speed on all vehicles manufactured prior to analyzer certification that are included in the Smog Check Program (except those powered by diesel engines). As a minimum, analyzers must be equipped with a spark plug wire direct pickup, a non-contact pickup, and an (on board diagnostics) OBD II interface connection. For analyzer certification, analyzers shall be capable of reading engine RPM on all spark ignition vehicles. Beginning with 1996 model year vehicles, the system shall be capable of detecting engine RPM via OBD II.

### 2.10 TESTING HEAVY-DUTY GASOLINE-POWERED VEHICLES

Manufacturers shall supply the analyzer with the hardware and software necessary to test heavy-duty gasoline-powered vehicles manufactured prior to certification. At a minimum, accessories shall allow for 40-foot motorhomes to be tested without degrading the emission analyzer response time and provide the technician with an accurate indication of the engine speed. If there is an appropriate category in Table 4, the default should be ASM.

### 2.11 DUAL EXHAUST

For vehicles with dual exhaust, the analyzer supplier shall provide a dual probe-and-hose arrangement, designed so that the flows from each tailpipe reach the main sample hose at the same time and shall have the same flow  $\pm 10\%$ . A quick-connect coupling may be used to connect an auxiliary probe and hose, but no quick-connect coupling shall be used in the primary single-exhaust path. The quick-connect fitting, if used, shall have a leakproof shutoff when not in use. The fitting for connecting the auxiliary hose shall be located at least 7 feet from the probe end of the main sample hose. The auxiliary hose length shall be equal to this probe-to-fitting distance  $\pm 3$  inches.

### 2.12 OEM AND AFTERMARKET CONSUMABLE PARTS

All consumable EIS parts (hoses, probes, filters, tachometer leads, cables, etc.) and BAR approved replacements shall meet or exceed the requirements of the applicable sections of this specification. In addition, all consumable parts including aftermarket replacements shall be marked with a BAR registered code to verify authenticity. This requirement applies to the part, not the part packaging. The code shall be permanent and easily visible. Manufacturers shall affix, stamp, engrave, print, etc. the code in a manner acceptable to BAR.