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RAVEM™ SPECIFICATIONS AND PRICING

RAVEM 3.2: For PM, NO_x, CO₂ and CO

The RAVEM 3.2 is designed to carry out on-board measurements of NO_x, PM, CO₂, and CO, while collecting Tedlar™ bag samples that can be further analyzed for other gaseous pollutants. The RAVEM 3.2 is available as a **Basic** system, or as a **Complete** system comprising all the accessories and tools necessary to carry out on-board emission measurements. The former is recommended when the RAVEM is to be added to an existing emission laboratory, whereas the latter is suggested where a new emission measurement unit is to be established. Two optional packages allow for the measurement and speciation of carbonyls and volatile organic compounds, respectively.

The **Basic** RAVEM system is priced at USD189,000, FOB Sacramento. It includes the following components:

- ❖ The RAVEM CVS system unit, containing:
 - The CVS dilution tunnel, complete with blower, HEPA air filter, and system for automatic control and stabilization of the CVS flowrate;
 - Sierra Instruments thermal mass flow sensor for calibrating the automatic flow control system, with bypass valve to protect the mass flow sensor from PM contamination during emission sampling;
 - EF&EE's patented isokinetic partial-flow exhaust sampling system, including the differential pressure gage, automatic throttle control, and connections for the raw gas sample line and the differential pressure lines from the exhaust probe;
 - Dilute particulate sampling system, including particulate filter holders for sample and background filters, mass flow controllers, and vacuum pump;
 - Gaseous bag sampling system, including internal sample bags for dilute exhaust and background air samples, provision for connecting external sample bags, mass flow controllers, and sample pumps;
 - National Instruments Fieldpoint Ethernet-compatible data acquisition and control system providing analog-to-digital, digital-to-analog, and digital I/O;
 - Trimble SV12 GPS receiver and antenna;
 - Sensors for relative humidity and barometric pressure;

- On-board Ethernet switch and Ethernet-to-serial converters for the GPS, gas analyzers, flow controllers, and automatic throttle controls;
- External connections for calibration gases, data cable, Ethernet connection, and sample tube to the gas analyzer assembly.
- ❖ Gas analyzer unit, comprising a military-type, water and dust-resistant, shock-mounted 19 inch rack containing:
 - California Analytical Instruments 400 HCLD heated chemiluminescent NO/NO_x analyzer, with on-board filter, pump, and dryer system for pressurized air;
 - California Instruments ZRH NDIR analyzer for CO₂ and CO with on-board Nafion™ sample dryer system;
 - Power, signal conditioning, and data cable connections;
- ❖ Laptop computer with Ethernet control link, RAVEM 3 control and data analysis software, Microsoft Excel and Visual Basic 6.0 pre-installed;
- ❖ Three isokinetic sampling probes, with nominal diameters of 5.6, 7.6, and 10.2 mm, suitable for the typical range of exhaust gas velocities;
- ❖ Two end-of-exhaust-pipe probe mounts to fit four-inch and five inch exhausts;
- ❖ 15 meters of insulated raw gas sampling line in various lengths, with connecting fittings;
- ❖ Two sets of PM filter holders, designed for installation on the CVS system unit;
- ❖ Ten sets of internal (15 liter) and 5 sets of external (60 liter) sampling bags for dilute exhaust gas and background air samples, with a separate container and quick-connect system for the external bags;
- ❖ Two sets of delta-pressure lines for the isokinetic sampling system, equipped with quick-connect fittings on both ends;
- ❖ Two sets of connecting cables;
- ❖ Operating manuals;
- ❖ Warranty covering defects in materials or workmanship for one year.

The **Complete** RAVEM system is offered as a convenience to our customers. Based on our extensive field experience using the RAVEM system, it includes the **Basic** RAVEM system plus all of the auxiliary systems and components needed to carry out emission testing. The only additional purchases required are: worktables and chairs, a diesel vehicle for transportation and carbon balance checks, cylinders of compressed gases for calibration, and a microbalance. These are best purchased in the country of use – the first three because they are prohibitively difficult to ship, and the last because of the need for local service.

The **Complete** RAVEM system is priced at USD 252,000, FOB Sacramento. Additional components beyond the basic system include:

- ❖ Uninterruptible power source/battery chargers for 12 and 24-volt vehicle electrical systems, with 30 meters of AC power cord;

- ❖ Portable, gasoline-powered AC generator to supplement vehicle electrical systems where necessary;
- ❖ Custom-built calibrator and leak check system for the differential-pressure lines and sensor;
- ❖ Three pressure regulators for zero, CO/CO₂ span, and NO_x span gases, and two sets of Teflon tubes with quick-connect fittings to conduct the gases to the CVS system unit;
- ❖ Gas cylinder dolly for safely transporting and supporting three cylinders at a time;
- ❖ One CO₂ regulator and metering valves for performing CO₂ recovery checks;
- ❖ Ten type “K” bare thermocouples and three thermocouple probes, with two sets of extension wiring;
- ❖ One set of three-way valves for diesel fuel supply and return lines, with two removable auxiliary fuel tanks for performing carbon balance checks;
- ❖ Laboratory balance (20 kg with 0.5 gram precision) for performing carbon balance and CO₂ recovery checks;
- ❖ Environics 4040 precision gas dilution system for performing linearity checks specified in 40 CFR 86;
- ❖ Ozone generator for performing NO₂ conversion checks specified in 40 CFR 86;
- ❖ Equipment for performing water and CO₂ interference checks specified in 40 CFR 86;
- ❖ Eight heavy-duty ratchet-straps for securing the system and gas analyzer units to the vehicles under test;
- ❖ An assortment of exhaust elbows, extension pieces, and adapters for common vehicle exhaust system sizes;
- ❖ Tool kit comprising all metric and English tools needed to install and maintain the RAVEM on a wide variety of vehicles;
- ❖ Spare parts kit, including spare sample pumps, flow controllers, laptop computer, air and sample filters, Tedlar bags, Swagelok fittings, stainless steel and Teflon tubing, electrical connectors and pins, and thermocouples;
- ❖ PM filter weighing cabinet, equipped with HEPA-filtered, positive air pressure ventilation, humidity and temperature monitor, and room humidifier with humidistat control to maintain constant humidity conditions in the weighing room;
- ❖ PM filters adequate for approximately 1000 emission tests.

Option 1: Carbonyl measurements -- This option comprises the additional equipment needed to measure emissions of carbonyls (aldehydes and ketones) according to U.S. EPA method TO-11a using DNPH cartridges. It is priced at USD 28,300 FOB Sacramento. It comprises the following specific elements of equipment:

- ❖ Two additional mass flow controllers, two DNPH cartridge holders, and two sample pumps to expose the DNPH cartridges to controlled flows of dilute exhaust gas;

- ❖ 1000 DNPH cartridges;
- ❖ Laboratory refrigerator for storing the DNPH cartridges and two portable coolers for transporting them to and from the field;
- ❖ One SRI high-performance liquid chromatography (HPLC) system configured to perform EPA method TO-11a, with accessories;
- ❖ Laptop computer with pre-installed software to operate the HPLC system and record data;
- ❖ Rack, syringes with adaptors, and 1000 vials for holding the eluent from the DNPH cartridges;
- ❖ Four vials of laboratory standard solution for calibration;
- ❖ Toxic clean-up kit for dealing with spills of acetonitrile.

Option 2: Speciation of gaseous hydrocarbons – This option comprises the additional equipment needed to determine the concentration of specific hydrocarbon gases such as methane, ethane, ethene, propane, propene, butane, butanes, and 1,3 butadiene in the dilute exhaust sample bags. This is considered important to adequately characterize the environmental impacts of CNG and other vehicles with spark-ignition engines. The option is priced at USD 32,500. It comprises:

- ❖ One SRI gas chromatograph system equipped with a flame ionization detector (FID) capillary column suited for light hydrocarbons analysis, with accessories and spare parts kit;
- ❖ Pressure regulators and connection tubing required for the GC-grade hydrogen FID fuel, helium carrier gas, and zero-grade compressed air used by the gas chromatograph system;
- ❖ Laptop computer with pre-installed software to operate the GC system and record data;
- ❖ Disposable cylinders containing gas standards for C1-C6 alkanes, C1-C6 alkenes, and 1,3 butadiene, with regulators;
- ❖ 15 additional sets of 60 liter Tedlar bags equipped with light-protective covers.

Option 3: Total hydrocarbon measurements – This option comprises the additional equipment needed to measure total hydrocarbons (THC) by flame ionization detector in real time, second-by-second, according to the methods specified by the U.S. EPA and ISO 8178 for diesel vehicles and engines (the method is also acceptable for gasoline, CNG, LPG, etc.). When combined with GC analysis of the integrated sample bag to determine methane, this method can also be used to determine non-methane hydrocarbon emissions. This option is priced at USD 22,900. It comprises:

- ❖ A removable heated probe for HC collection, with probe tip fitting for calibration gas, configured to fit a sample port in the RAVEM dilution tunnel;
- ❖ A military-type, water and dust-resistant, shock-mounted analytical rack containing

- One California Analytical Model 300 heated flame ionization detector with built-in heated sample pump;
- One 5 meter (16 foot) heated sample line;
- Temperature control units and connection wiring for the heated line and heated probe;
- Storage area for the heated sample line;
- ❖ Spare parts kit for the analyzer, including spare sample pump and 10 spare sample filters,
- ❖ Provision in the RAVEM system unit for controlling the flow of HC calibration gas and zero air to the probe-tip calibration port.

Warranty

Engine, Fuel, and Emissions Engineering warrants all components of the RAVEM system against defects in materials or workmanship for a period of one year from the time it is first placed into service. EF&EE will repair or replace, at its option, any RAVEM system component that fails during the warranty period. This warranty does not apply to mechanical damage or other failure suffered as a result of abuse or improper operation, or to consumable items such as filters and Tedlar bags.