



Reference Method
Portable FTIR Gas Analyzer System

RM-SYS

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2010

1. INTRODUCTION

The Gasmet-USA™ RM-SYS gas analyzing system is a "hot-wet" system incorporating a sample probe, sample line, sample interface and a FTIR gas analyzer. The gas-analyzing system described herein is designed and field tested for the monitoring of Oxides of Nitrogen (NO_x), Carbon Monoxide (CO), Carbon Dioxide (CO₂), Volatile Organic Compounds (VOCs), Hazardous Air Pollutants (HAPs), Oxygen (O₂) and other related compounds in engine exhaust gases. The system has the ability, with simple configuration changes, to measure additional compounds without factory assistance. All gases are measured with the Gasmet Technologies, Oy Gasmet™ DX-4000 Fourier Transform Infra Red (FTIR) gas analyzer except Oxygen. Oxygen (O₂) is measured with a Zirconium Oxide (ZrO₂) O₂ sensor located in the Portable Sampling Unit (PSU).

The Gasmet-USA™ RM-SYS gas analyzing system heated sample probe is supplied by M&C products model PSP. A two micron filter element is mounted within the probe 316 SS filter housing. The probe connects to the sample interface unit by the supplied heated sample line. The sample line is constructed of a 316 SS corrugated tube with constant power density heating elements and thermocouple temperature indication. The heated sample line terminates at the Portable Sampling Unit (PSU).

The PSU sample interface module houses a heated filter, and a heated sample pump. The PSU also provides temperature control of the probe, sample oven and heated sample lines. Connection for required Nitrogen supply, Manual/Auto Pump control and Manual Probe calibration control are features of the PSU.

The Gasmet DX-4000 FTIR gas analyzer sample inlet connects to the PSU using supplied 3 feet heated tube. Control of the system and data collection is provided by RS232 serial communications to the supplied Calcmet™ software.

A customer-supplied industrial laptop computer is required for operation of the system. The computer can operate under any Microsoft Windows™ operating system. Gasmet Technologies Calcmet™ and AQA RMGuide™ software along with all manuals and Gasmet Reference Library. are provided on the Customer CD to be installed on the computer. A bottle of zero grade nitrogen is required for the proper operation of the system. A 24 hour Factory Acceptance Test (FAT) will be performed prior to shipment to verify system stability. During the FAT, the system will operate continuously, sampling a simulated wet flue gas. Warranty is one year from ship date and remote support during normal business hour is free from the warranty period. The system is comprised of the major components defined in Table 1.

Table 1: Major Components

Item	Description	Manufacturer
01	Sample Probe	M&C PSP-TC.
02	Heated Sample Lines	AQA
03	Heated Sample Interface	AQA
04	FTIR Gas Analyzer	Gasmet DX-4000-5M
05	Data Acquisition	Gasmet Calcmet V11.x

2. DESCRIPTION

A. Sample Probe

The M&C PSP4000HC sample probe conducts the sample from the source, filters the sample for particulate matter and conveys this filtered sample to the heated sample line. The Probe is equipped with a port to introduce calibration gases into the filter body. Filtration is by a 2 micron Teflon element. A quick disconnect mounted sample line holder is provided to prevent stress on the sample tube. Figure 1 illustrates the supplied sample probe.

The flue gas is first drawn through a 3/8" O.D. (8 mm) probe tube. The probe tube connects to the filter body by supplied Swagelok compression fitting.

The filter body is heated to 200°C by a 320-watt resistance heater mounted inside the filter body housing. Power (110 V 60 Hz) is supplied by the Portable Sampling Unit (PSU).

A carrying handle and a chain for in situ attachment are mounted on the heat-isolated housing. The integrated micro-filter element with a fineness degree of 2 µm reliably retains solid impurities and can be changed easily. For heavy-oil firing measurements, a stainless-steel filter cartridge is optionally available. Please refer to M&C PSP4000H/C manual for more detail on the sample probe supplied.

B. Heated Sample Lines

The sample line is constructed of a 316 SS corrugated tube with constant power density heating elements and thermocouple temperature indication. Closed cell silicone foam is used to insulate the heated core and then covered with a poly-propylene jacket. Two, 1/4" O.D PFA Teflon tubes are installed within the heated core. The sample tubes are removable and replaceable. The configuration is capable of maintaining 200°C sample gas temperature in 0°C ambient temperature. The length of the heated sample line supplied is 50 feet. The minimum bend radius of the tubing bundle is 18 inches.

Figure 2: Heated Sample Line



by a 6 pin threaded connector.

Figure 1: Sample Probe



The heated sample line temperature is maintained up to 200° C by a digital temperature controller. A "K" type thermocouple is embedded in the power end of the heated sample line, approximately ten feet from the end, and connected to the controller for temperature indication. The 110 VAC 10 Amp current flows through a solid state relay. The temperature controller and relay are located in the PSU Sample Interface and connect to the heated line

C. Portable Sampling Unit (PSU)

The PSU Sample Interface provides sample gas interface to the Gasmet™ DX-4000 FTIR gas analyzer. The PSU unit contains a built-in oxygen sensor for determination of sample gas O₂ concentration. The oxygen sensor uses a zirconium cell and the measured values are transmitted to the DX-4000 analyzer's DSP electronics. The analyzer transmits this information to Calcmeter software together with the IR spectrum through serial cable. No additional I/O hardware is required for the computer running Calcmeter software.

The PSU incorporates a heated head diaphragm sample pump capable of sustaining sample flow rates to 8 Liters per Minute (LPM) at temperatures of up to 2000°C. The Sample Interface can be used on flue gas streams up to 40% water vapor by volume and acid dew points to 200°C.

Four digital temperature controllers and associated circuits are used for PID temperature control of the Probe, Sample Oven and the two external heated sample lines. Relay interlocks assure that the sample pump will not turn on if heated zones are outside set tolerance. Panel mounted connectors are provided next to the sample inlet for quick connection of sample line power.

A vacuum gauge is provided for convenient leak check indication and for monitoring conditions outside the sample interface.

Two-way rocker switches provide selection of power to the unit and manual control of the sample pump.

Three way pneumatic valves are provided for introducing zero and span gases into the system. These gases can be directed either to the sample probe or directly to the gas analyzer using either the low or high flow meters.

Figure 3: PSU Sample Interface



D. GASMET DX-4000 FTIR Gas Analyzer

The Gasmet™ DX-4000 multi-component gas analyzer is based on Fourier Transform Infrared (FTIR) spectroscopy. The GASMET™ DX-4000 user manual is provided in a separate document. The analyzer is comprised of a 0.4-liter volume 5.0 meter optical path heated sample "white" cell, interferometer, Peltier-cooled MCT detector, electronic circuit boards and internally mounted power supply. All analyzer components are mounted on a vibration isolated, rolled metal frame connected to the bottom of the NEMA 12 analyzer case.

The analyzer requires 110-120 VAC 50/60Hz and is supplied with a standard instrument power cord. The

Operation of the gas analyzer is by the customer-supplied system Laptop Computer and CALCMET™ for Windows software. An RS232 cable with DB9 connectors has been supplied for connection between the laptop Communications Port 01 and the analyzer. The connection to the analyzer is labeled GASMET™ on the cable.

An Ultra pure Nitrogen (N2 99.99%) gas cylinder is required for proper zeroing (baseline) of the FTIR analyzer. Nitrogen and calibration gases are to be supplied by the customer.



Figure 4: Gasmet DX-4000

E. Computer Interface

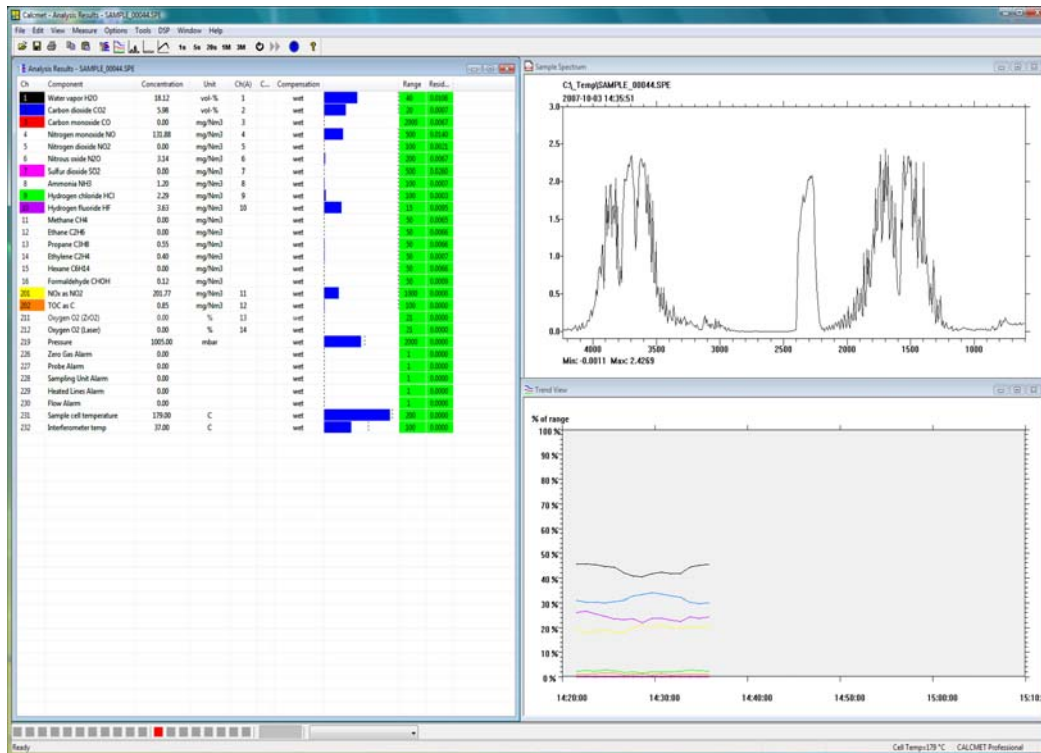
A customer-supplied laptop computer is required for operation of the system. The computer can operate under any Microsoft Windows™ operating system. Gasmet Technologies Calcmet™ software along with all manuals and the Gasmet Reference Spectra Library are provided on the Customer CD to be installed on the computer. RMGuide™ software is also provided to assist the operator in performing ASTM and EPA reference method tests procedures.

Calcmet™ is the software package that controls the Gasmet DX-4000 and collects single beam transmittance spectra per user defined intervals. The transmittance spectra is then converted to absorbance spectra and analyzed for the compounds configured by the user using reference spectra. Calcmet provides an easy to use interface to the FTIR gas analyzer, stores and displays the sample spectra and performs the multi-component analysis using Gasmet Technologies' patented modified Classical Least Squares algorithm.

RS232 serial communication (IEE 802.3) is used to control and acquire data from the Gasmet DX-4000. The serial port used must be 8088 legacy communications port 1 (IRQ4, 02E8) or 2 (IRQ3, 03E8). A USB to serial adapter is commonly used with current laptops that do not have serial ports.

CALCMET SPECIFICATIONS	
Data acquisition time:	1 – 500 seconds, time weighted average of individual scans lasting 100 ms each. Data acquisition may be configured for 5, 20, 60,180 and 300 second interval.
Detection limit:	< 3 x spectral baseline noise
Linearity deviation:	< 2 % of reference concentration
Linearity correction:	Automatic, multi-point fitting of calibration curve
Cross-Interference:	< 4 % of reference concentration, cross-interfering components are included in multi-component analysis
Quality Assurance:	Residual absorbance from analysis is monitored and results invalidated if residual is too high
End User License	
Standard version:	Unlimited Site License.
Pro version:	Single user license, protected with a HASP USB key. Calcmet Pro features are contained in standard version distribution package, but are hidden when Calcmet Pro license key is not present.

Figure 5: Typical Calcmet Display



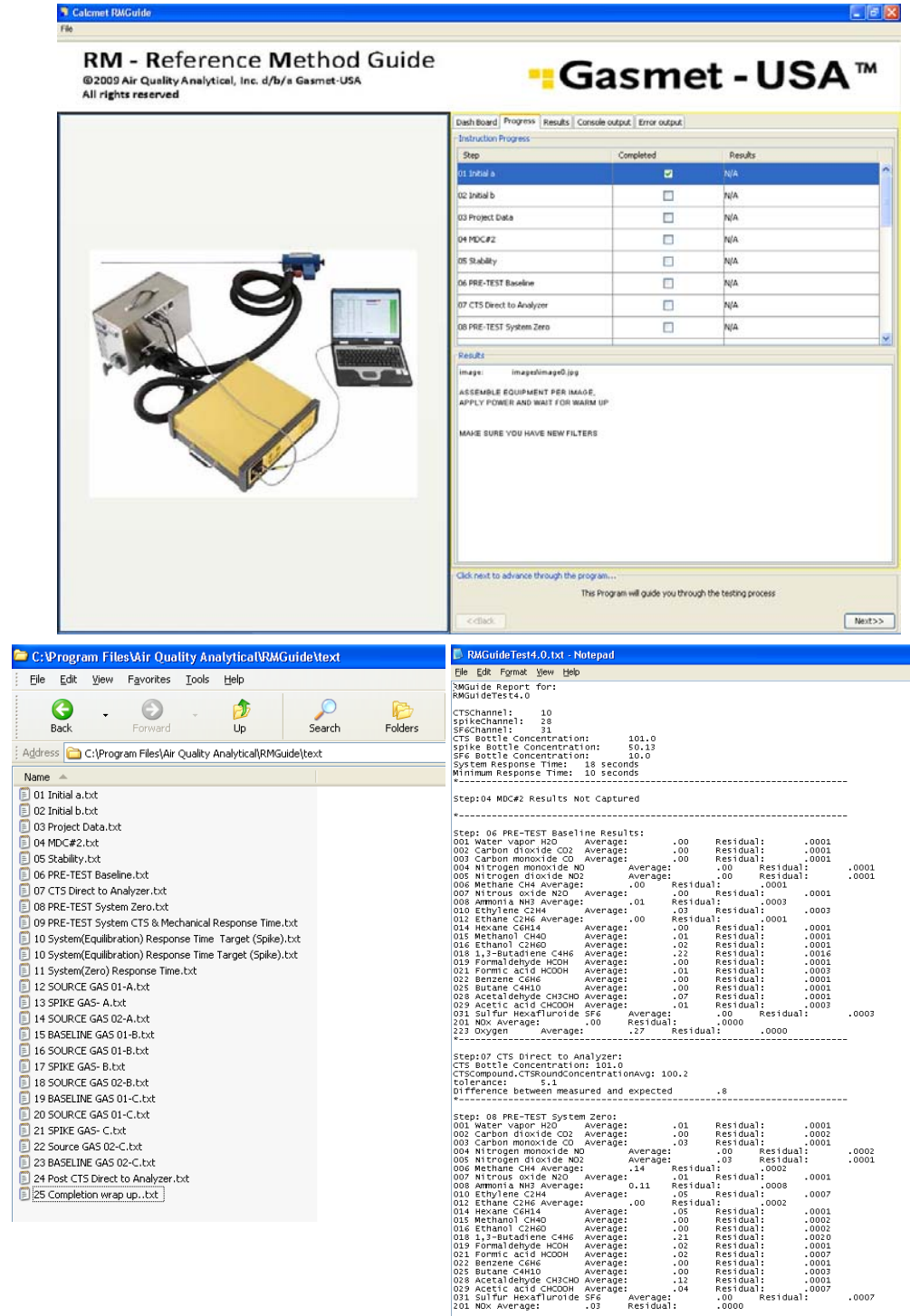
RMGuide is a Java application provided with the proposed system. RMGuide assists the operator in performing ASTM-6348 FTIR test procedures. RMGuide can also be used for various EPA reference method tests. RMGuide breaks down the ASTM test method into 24 steps. Data is collected at each step, by operator initiation, using the Dynamic Data Exchange (DDE) feature of the Calcmnet software program.

The Dashboard tab of RMGuide provides user configurable text and graphics for each step of the ASTM-6348 procedure.

The Progress tab provides a summary of the various steps while the Results tab provides a running summary of all tests completed.

The Console Output tab provides real-time information on DDE data and the Error Output tab keeps a running log of any parameters outside defined tolerances.

Figure 6: RMGuide Software



The screenshot displays the RMGuide software interface. The main window is titled "RM - Reference Method Guide" and includes a "Gasmet - USA™" logo. The interface is divided into several tabs: "Dashboard", "Progress", "Results", "Console output", and "Error output".

The "Progress" tab shows a table of test steps:

Step	Completed	Results
01 Initial a	<input checked="" type="checkbox"/>	N/A
02 Initial b	<input type="checkbox"/>	N/A
03 Project Data	<input type="checkbox"/>	N/A
04 MDC#2	<input type="checkbox"/>	N/A
05 Stability	<input type="checkbox"/>	N/A
06 PRE-TEST Baseline	<input type="checkbox"/>	N/A
07 CTS Direct to Analyzer	<input type="checkbox"/>	N/A
08 PRE-TEST System Zero	<input type="checkbox"/>	N/A

The "Results" tab displays test results for "RMGuideTest4.0":

```

CTSSChannel: 10
SpikeChannel: 28
SFCChannel: 21
CTS Bottle Concentration: 101.0
SFC Bottle Concentration: 50.13
SFC Bottle Concentration: 10.0
System Response Time: 18 seconds
Minimum Response Time: 10 seconds
    
```

The "Console output" tab shows detailed test results for various compounds, including Water vapor, Carbon dioxide, Nitrogen monoxide, and various hydrocarbons. The results are presented in a table format with columns for the compound name, average concentration, and residual value.

The "Error output" tab shows a log of any parameters that fall outside defined tolerances.

Below the main software window, a Notepad window displays the following test results:

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Step:04 MDC#2 Results Not Captured

Step:06 PRE-TEST Baseline Results:
001 Water vapor H2O Average: .00 Residual: .0001
002 Carbon dioxide CO2 Average: .00 Residual: .0001
003 Carbon monoxide CO Average: .00 Residual: .0001
004 Nitrogen monoxide NO Average: .00 Residual: .0001
005 Nitrogen dioxide NO2 Average: .00 Residual: .0001
006 Methane CH4 Average: .00 Residual: .0001
007 Nitrous oxide N2O Average: .00 Residual: .0003
008 Ammonia NH3 Average: .01 Residual: .0003
009 Ethylene C2H4 Average: .02 Residual: .0003
010 Ethane C2H6 Average: .00 Residual: .0001
011 Hexane C6H14 Average: .00 Residual: .0001
012 Methanol CH4O Average: .01 Residual: .0001
013 Ethanol C2H6O Average: .02 Residual: .0002
014 1,3-Butadiene C4H6 Average: .21 Residual: .0016
015 Formaldehyde HCHO Average: .00 Residual: .0001
016 Formic acid HCOOH Average: .01 Residual: .0003
017 Benzene C6H6 Average: .00 Residual: .0001
018 Butane C4H10 Average: .00 Residual: .0001
019 Acetaldehyde CH3CHO Average: .07 Residual: .0001
020 Acetic acid CH3COOH Average: .01 Residual: .0003
021 Sulfur Hexafluoride SF6 Average: .00 Residual: .0003
201 NOx Average: .00 Residual: .0000
223 Oxygen Average: .27 Residual: .0000

Step:07 CTS Direct to Analyzer:
CTS Bottle Concentration: 101.0
CTSCompound/CTSSpikeConcentrationAvg: 100.2
Tolerance: 5.1
Difference between measured and expected: .8

Step:08 PRE-TEST System Zero:
001 Water vapor H2O Average: .01 Residual: .0001
002 Carbon dioxide CO2 Average: .00 Residual: .0002
003 Carbon monoxide CO Average: .03 Residual: .0001
004 Nitrogen monoxide NO Average: .00 Residual: .0002
005 Nitrogen dioxide NO2 Average: .01 Residual: .0001
006 Methane CH4 Average: .14 Residual: .0002
007 Nitrous oxide N2O Average: 0.11 Residual: .0008
008 Ammonia NH3 Average: 0.11 Residual: .0008
009 Ethylene C2H4 Average: .05 Residual: .0002
010 Ethane C2H6 Average: .05 Residual: .0001
011 Hexane C6H14 Average: .00 Residual: .0001
012 Methanol CH4O Average: .00 Residual: .0001
013 Ethanol C2H6O Average: .00 Residual: .0002
014 1,3-Butadiene C4H6 Average: .21 Residual: .0020
015 Formaldehyde HCHO Average: .02 Residual: .0001
016 Formic acid HCOOH Average: .02 Residual: .0007
017 Benzene C6H6 Average: .00 Residual: .0001
018 Butane C4H10 Average: .00 Residual: .0003
019 Acetaldehyde CH3CHO Average: .12 Residual: .0001
020 Acetic acid CH3COOH Average: .04 Residual: .0007
021 Sulfur Hexafluoride SF6 Average: .00 Residual: .0007
201 NOx Average: .03 Residual: .0000
    
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