



# Multi-functional Pyrolyzer

from Frontier Laboratories

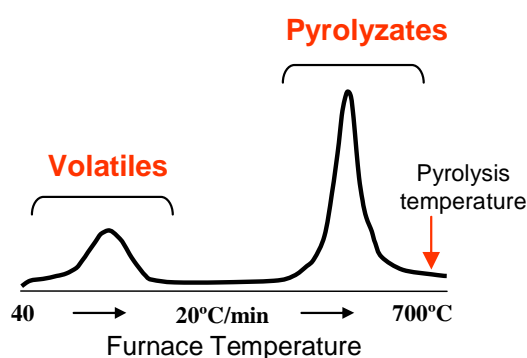
**Flexible**

**Versatile**

**Guaranteed reproducibility**

# Versatile

This is the most versatile of any Gas Chromatographic inlet system available. Most liquids and solids can be chemically characterized using five powerful thermal techniques.



## Evolved Gas Analysis (EGA)

EGA provides a whole thermal profile of the sample. A short 2.5 m deactivated capillary tube connects the Frontier multi-functional pyrolyzer and the GC detector. As the sample temperature increases, typically 40 to 700°C, compounds “evolve” from the sample matrix through TD and/or Py are detected. EGA enables the scientist to determine the proper temperatures for TD and Py for the following measurements.

## Thermal Desorption (TD) Analysis

The furnace temperature is programmed up to an intermediate temperature mostly below 300°C, and compounds are desorbed as a function of their boiling points. The volatile compounds are first trapped at the head of the column, and then chromatographically separated and detected. Thus obtained results are quite effective to evaluate additives and residual volatiles in the sample.

## Pyrolysis (Py) – “Single-Shot” Analysis

Pyrolysis is used for macromolecular and other non-volatile materials. When a sample is rapidly heated (<20msec) to high temperatures typically at 500°C or above, chemical bonds are broken. The resulting fragments are chromatographically separated, producing a pyrogram. The pyrogram is used to characterize the nature of the original sample.

## Thermal Desorption / Pyrolysis - “Double-Shot” Analysis

“Double-Shot” is the unique combination of *Thermal Desorption (TD)* and *Pyrolysis (Py)*. TD is used to identify volatile compounds in the sample such as residual solvents, reaction products, monomers, and additives like antioxidants and stabilizers. Py is used to characterize the polymer.

## Heart cut - EGA Analysis

The EGA thermogram is used to profile the sample compounds. Each fraction of the sample can be automatically cryo-trapped on the front of the GC column and then analyzed and characterized using heart cutting techniques.



# Flexible

A full range of accessories are available which give the multi-functional pyrolyzer the flexibility needed for optimum performance in all operating modes

## Carrier Gas Selector

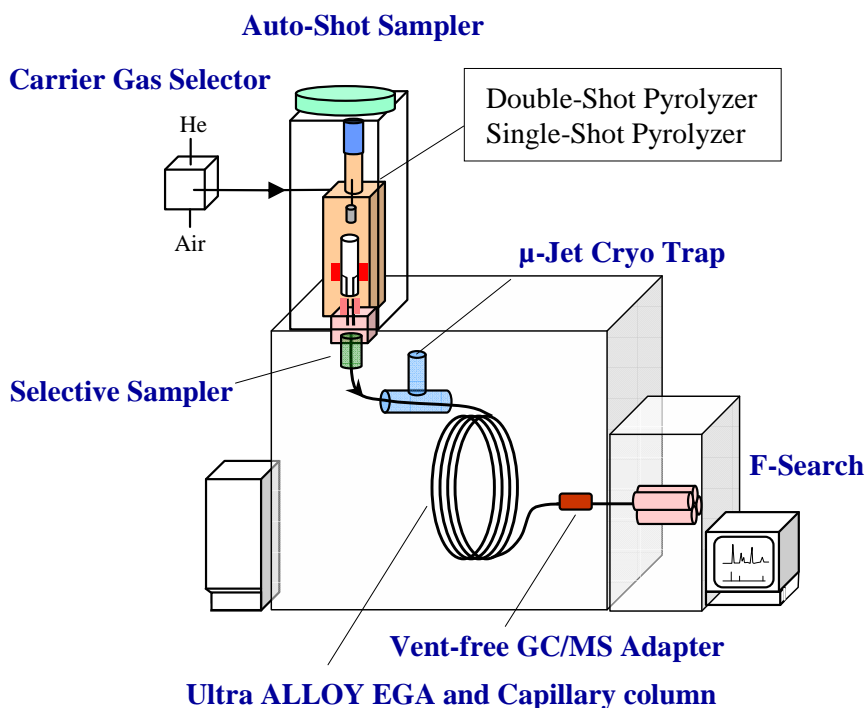
Enables the operator to select between two gases. Helium is nominally used. Air and oxygen are used when performing reaction pyrolysis.

## Selective sampler

Sample fractions can be automatically vented (i.e., cut) or directed to the analytical column.

## Auto-Shot Sampler

All sampling techniques can be fully automated using software. Up to 48 samples can be analyzed using the three (Single-Shot, Double-Shot and HC-EGA) and EGA methods separately in a labor saving mode.



## $\mu$ -Jet Cryo Trap

Compounds are focused at the head of the column prior to analysis. Nitrogen flow cooled by liquid nitrogen cools the trap down to  $-196^{\circ}\text{C}$  within 2 min.

## F-Search

Utilizes a patented search algorithm to tentatively identify samples based on their pyrogram or EGA thermogram of the polymer using MS.

## Ultra-ALLOY® EGA Tube and Capillary Columns

A patented multi-step process yields a deactivated stainless steel surface which is stable at temperatures greater than  $400^{\circ}\text{C}$ . Ultra-ALLOY columns and EGA tubes are the perfect match for all modes of the multi-functional pyrolyzer.

## Vent-free GC/MS Adapter

Enables the operator to change columns without venting the MS. Switching between the EGA mode and one of the other modes is simple. MS recovery time is less than 2 minutes.



# Detailed Sample Characterization

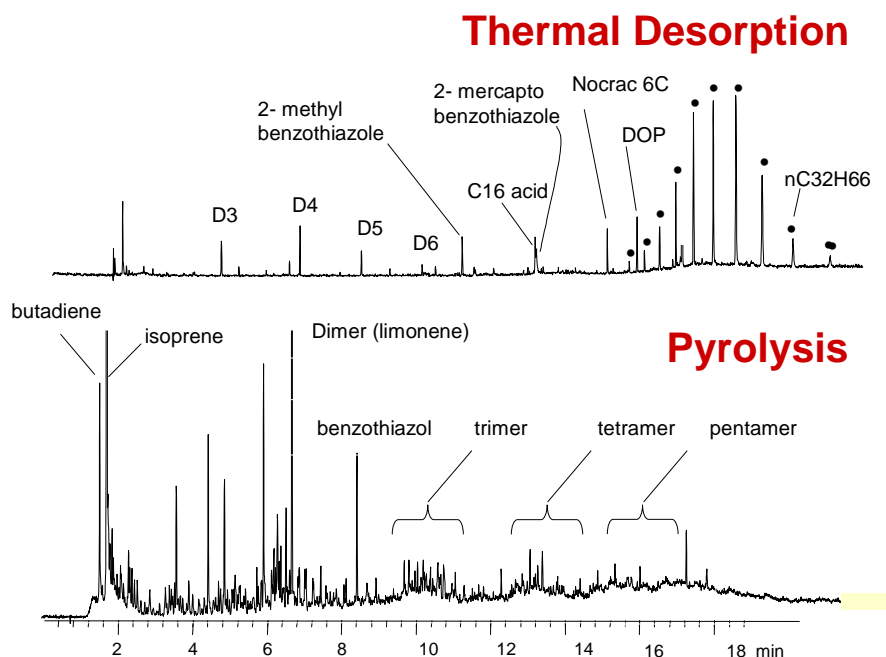
## Double-Shot™ Analysis : Unique combination of TD and Pyrolysis

### Thermal Desorption (TD)

The sample cup is dropped into the  $\mu$ -furnace at 40°C. The furnace is programmed to 320°C at 20°C/min. The volatile compounds are re-concentrated using  $\mu$ -jet cold trap. The GC subsequently separates the desorbed volatile compounds. The mass spectrum are used to identify each compounds.

#### Chromatograms of a formulated rubber sample

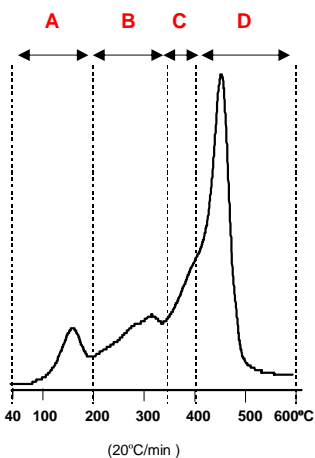
Column: Ultra ALLOY-5 (MS/HT), 30m x 0.25mm id, 0.25  $\mu$ m film)  
Column temp: 40–320°C (20°C/min), 50  $\mu$ g sample



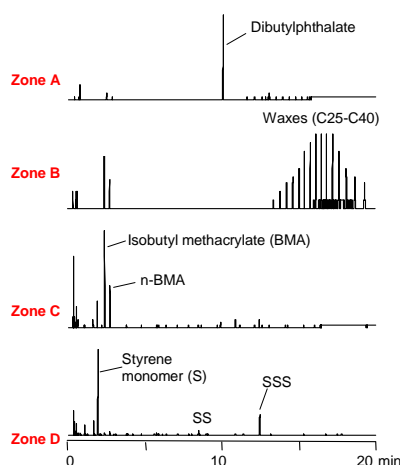
### Pyrolysis (Py)

Once the thermal desorption is complete, the sample cup is lifted out of the  $\mu$ -furnace. The  $\mu$ -furnace is heated to 600°C and the sample cup is dropped back into the furnace. The non-volatile portion of the sample is pyrolyzed. The pyrogram can be matched with standard pyrograms using the F-Search Pyrolysis Library.

#### EGA analysis of a composite ceramic/polymer



#### GC/MS analysis of each EGA zone



### Heart-cut EGA-GC Analysis

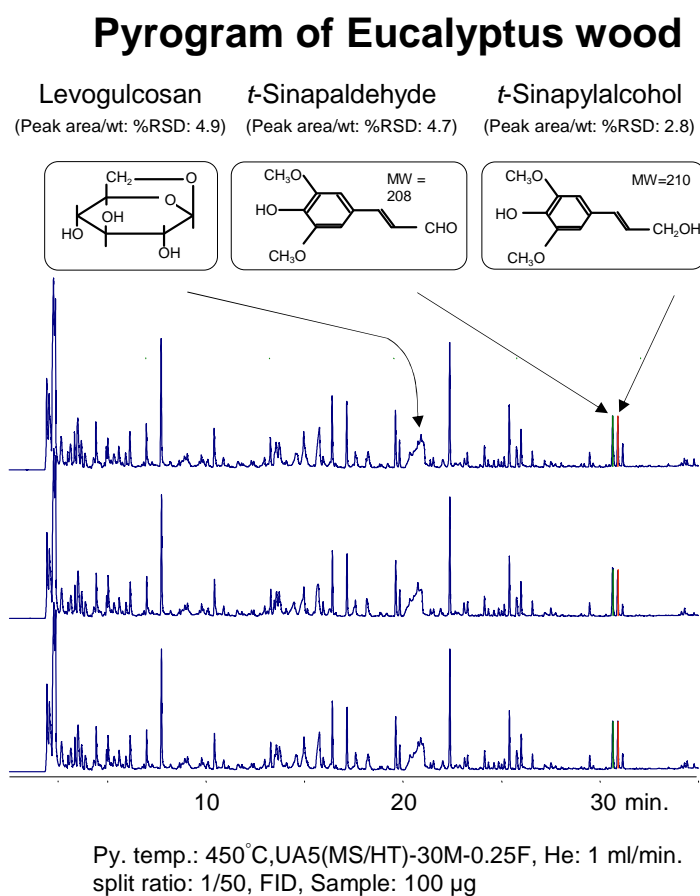
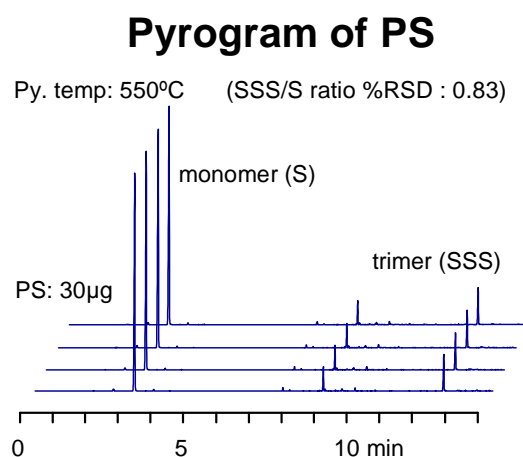
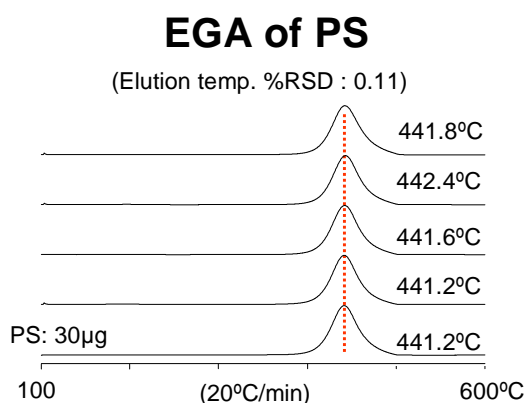
It may be important to characterize all fractions of a sample. Low boiling fractions may be additives: plasticizers, anti-oxidants, etc.. Other fractions may reveal an impurity, or explain the reasons for process problems. Each heart-cut can be characterized by GC/MS. Pyrolysis of the higher boiling fractions is used to identify a specific polymer blend using Frontier's F-search polymer libraries



# Reproducible

**GUARANTEED REPRODUCIBILITY!** Frontier is the only manufacturer that publishes a reproducibility specification for their pyrolyzer. Frontier guarantees that the styrene trimer to monomer ratio (SSS/S) of polystyrene (PS) pyrolyzates will be less than 3% RSD. The amazing reproducibility of the Frontier system can be attributed to the simplicity and ease of placing the sample in the Eco-cup, the patented design of the vertical  $\mu$ -furnace, the inertness of the sample path and the minimized dead volumes. Frontier provides a level of precision and accuracy never before seen in conventional pyrolysis-GC/MS.

These two examples shown in the left side illustrate the reproducibility of the guaranteed system in two of the most common modes of operation using PS. The other example of the right side demonstrates fairly good reproducibility even for polar compounds formed from natural polymers such as wood. Look at the data and judge for yourself.

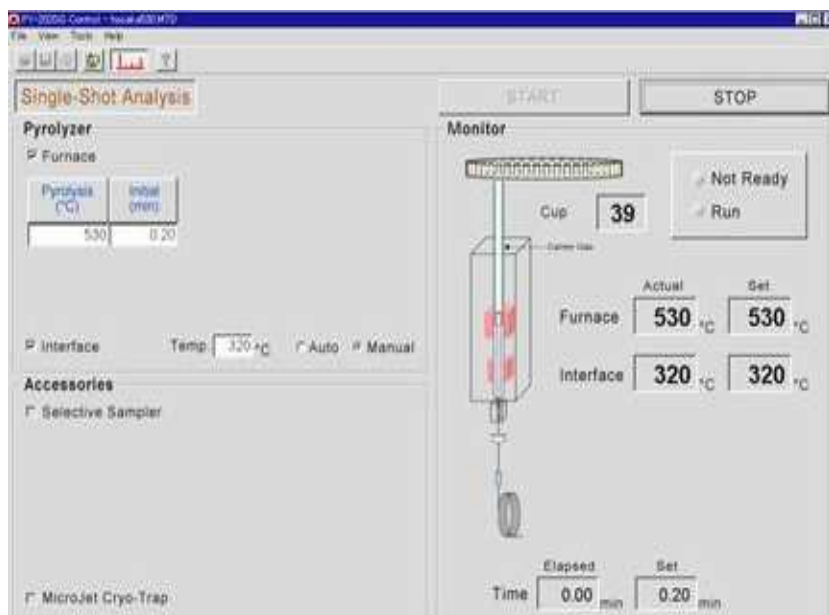
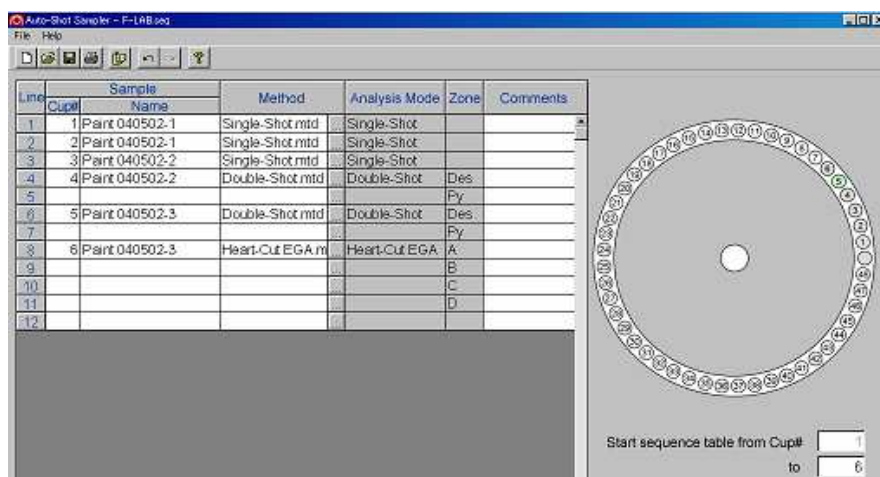


# Automated - Auto-Shot Sampler

**Auto-shot sampler mountable up to 48 samples combined with the Frontier multi-functional pyrolyzer provide guaranteed reproducibility in all operating modes – automatically in a labor-saving mode.**



Samples may be analyzed in sequence or at random. The complete sample method is set up using Frontier's software installed on the PC controlling the GC. Status is monitored on-screen. Samples already analyzed are noted in green, and the samples to be analyzed are shown in red.



This is a representative screen. It displays the mode of operation for the sample being analyzed as well as the current status of the inlet. The number of the sample being analyzed, position of the cup and the carrier gas flow rate are displayed in real time.



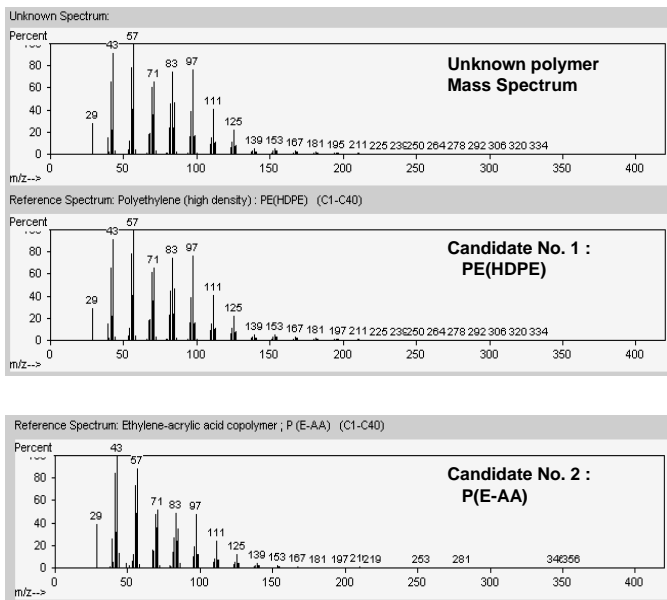
# Polymer Identification

Frontier Laboratories “**F-Search**” contains EGA & pyrogram polymer libraries. The libraries use a patented search algorithm which enables the chemist to identify unknown polymeric materials rapidly and unambiguously. The libraries contain integrated MS spectra and pyrograms/thermograms for 165 polymers. The chemist can easily edit or customize the libraries to fit specific chemical applications.

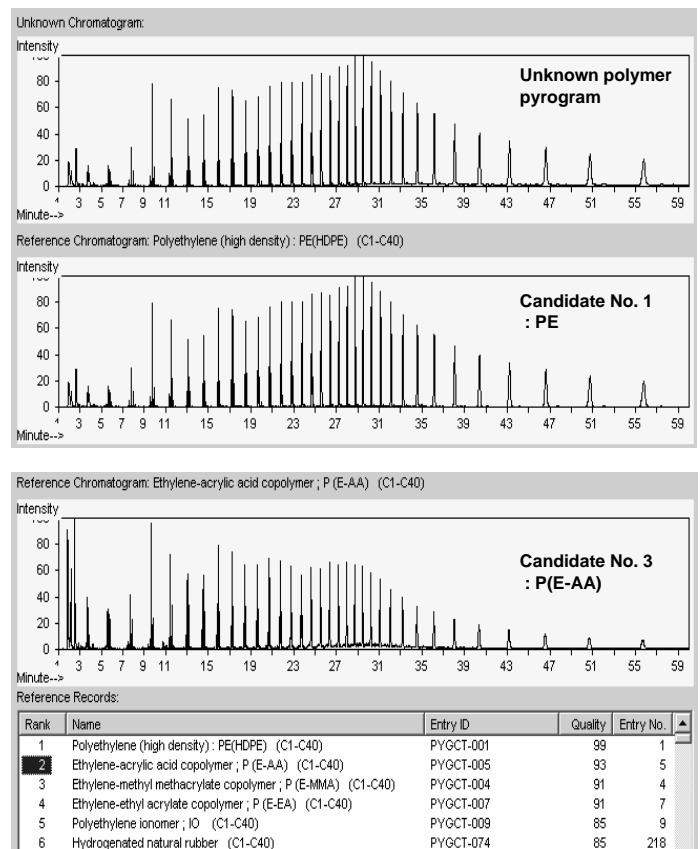
F-Search is compatible with GC/MS data obtained using Thermo Electron, Agilent, Shimadzu, and JEOL instruments. Data generated using GC/MS systems manufactured by these companies can also be interpreted after converting them to a NetCDF (AIA) file.

The partial results from a typical library search are illustrated below

The average spectrum of the unknown along with the averaged spectrum of the two best matches are shown. A table showing match quality is also presented.



Rank	Name	Entry ID	Quality
1	Polyethylene (high density): PE(HDPE) (C1-C40)	PYGCT-001	99
2	Ethylene-acrylic acid copolymer; P (E-AA) (C1-C40)	PYGCT-005	93
3	Ethylene-methyl methacrylate copolymer; P (E-MMA) (C1-C40)	PYGCT-004	91
4	Ethylene-ethyl acrylate copolymer; P (E-EA) (C1-C40)	PYGCT-007	91
5	Polyethylene ionomer; IO (C1-C40)	PYGCT-009	85



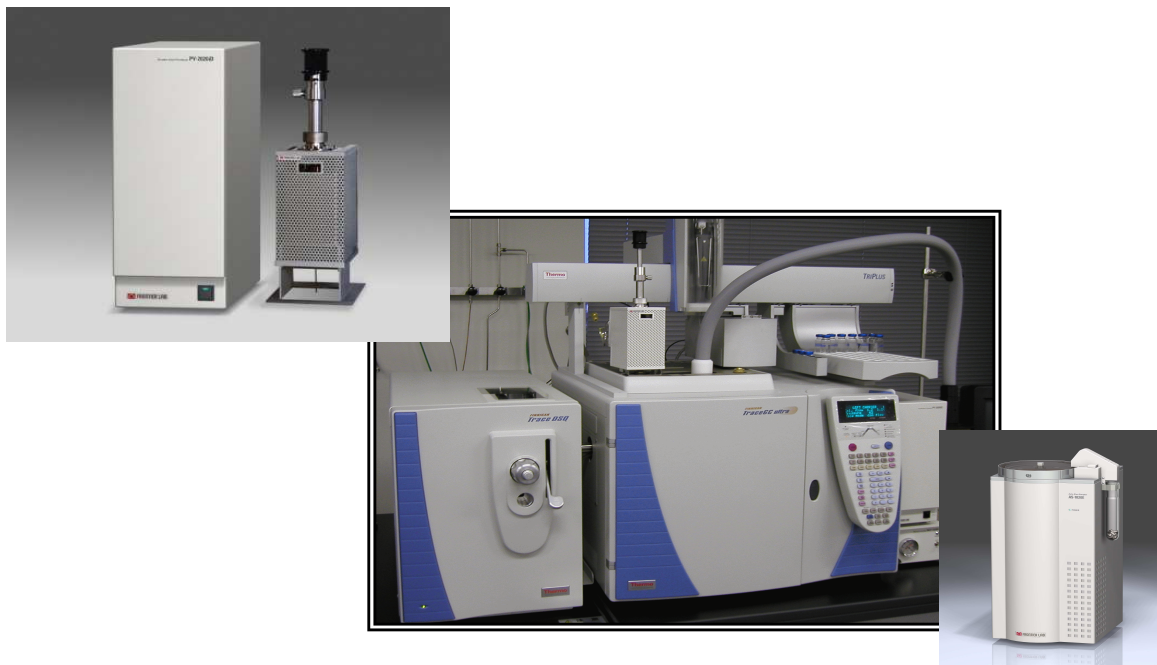
A Comparison of the pyrograms to the unknown data is also shown.



# Do you want to learn more about the most flexible, versatile and reproducible pyrolyzer ever existed?

Information about the system, any of the accessories discussed, technical data sheets on the various modes of operation and overall system performance is available from Thermo Electron. The application library, also available from Thermo Electron has over 100 briefs for your review.

## Multi-functional pyrolyzer



**Auto-Shot Sampler**

**Thermo Electron Corporation: [www.thermo.com](http://www.thermo.com)**



Frontier Laboratories: [www.frontier-lab.com](http://www.frontier-lab.com)