Falcon Analytical makers of the . . . CALIDUS micro GAS CHROMATOGRAPH

Rethinking the Anatomy of the Gas Chromatograph

GCC 2014

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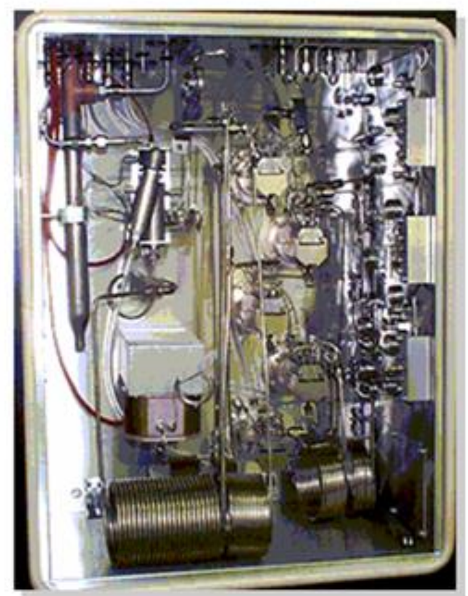
Size of Traditional GCs Dictated by Large, High Thermal Mass Ovens

- *Requires More Material*
- *Requires More Space*
- *Requires More Power*
- *Greatly Inhibits Modularity*

Conventional GC Oven

Large Thermal Mass



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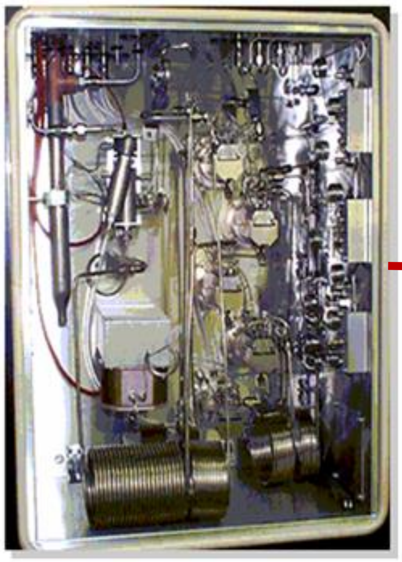
Eliminating the Large, High Thermal Mass Oven is the Definitive Starting Point For Rethinking the Anatomy of GCs

Conventional GC Oven

Large Thermal Mass



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A Few Commercially Available GCs Have Eliminated the Large, High Thermal Mass Oven

- ***New Designs and Patents have Focused on Directly Heating the GC Columns***

US Patents Relating to Fast GC Analysis

- 8,414,832 – Resistively heated stainless steel column and its thermal management
- 8,591,630 – Capillary column inserted into a resistively heated metal tube
- 5,589,630 – A fast temperature program module
- 5,437,179 – Reduced dead volume to increase analysis speed
- 5,310,681 – Flash heating of a trap (vapor concentrator device)

With the Large Oven Eliminated . . .

- GC components can be designed in micrometer rather than millimeter dimensions – much smaller.
- Analyzer weight can be reduced by a factor of 10 or more, i.e. 20 lbs vs. 200 lbs
- Power consumption can be reduced by a factor of 10 or more, i.e. 300 watts vs. 3000 watts

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GC Size Reduction Benefits

- *Placement strategies become more functional, cost-efficient and compact*
- *Lab bench space is greatly reduced*
- *GC's become far more transportable*
- *Modularity of major subassemblies is enabled, i.e. columns, detectors and sample transport*

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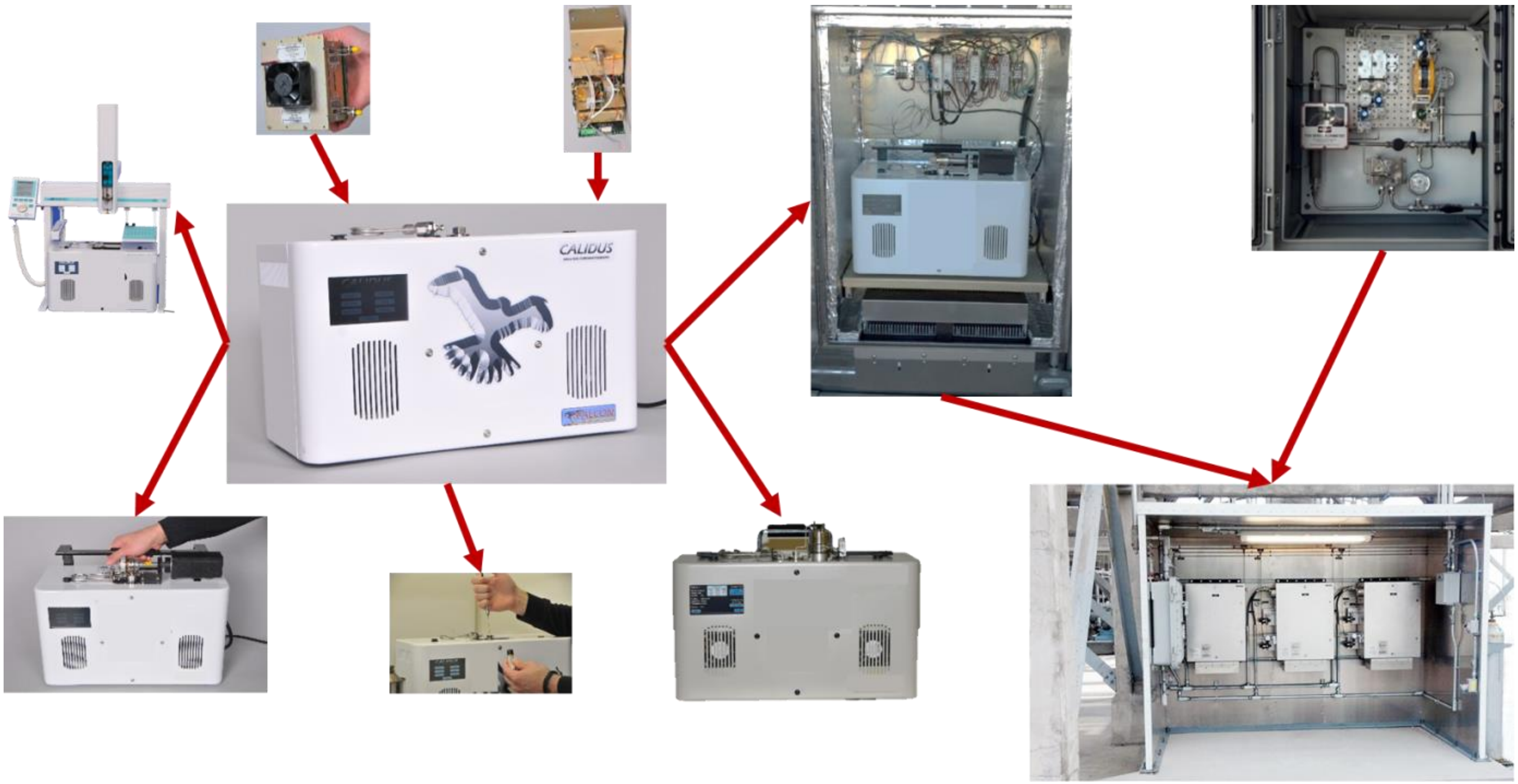
The New GC Anatomy

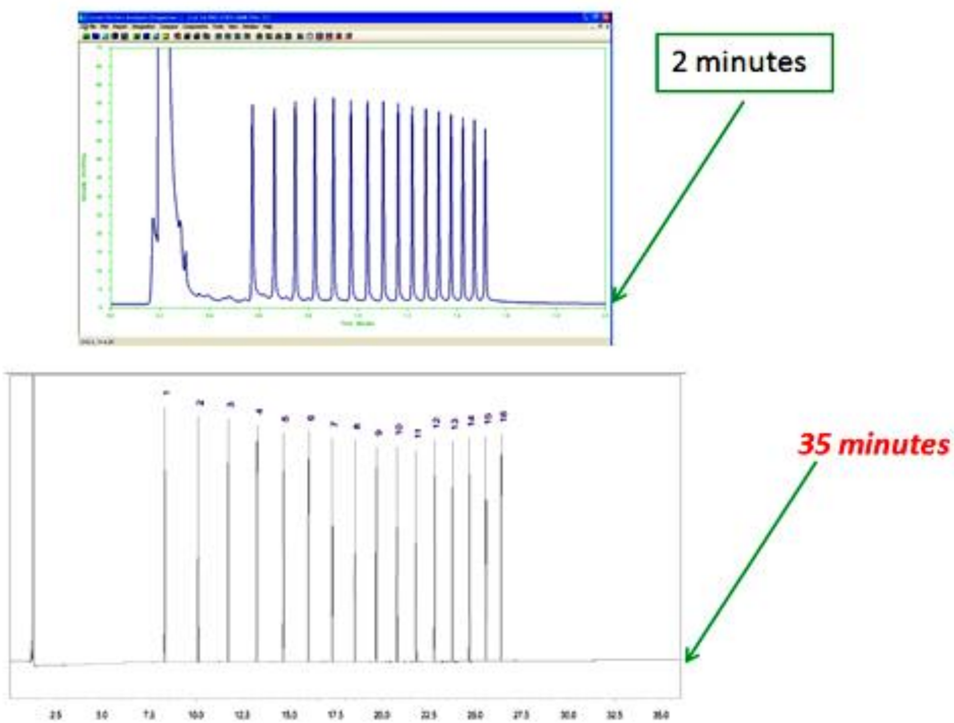


Analysis Enhancements

- Faster Heating and Cooling of the Column(s)
- Reduced "dead volume"
- Analysis Times 10 - 50 Faster than Conventional GCs
- Greater Component Resolution Capability
- Greater Long Term Stability

Examples of Analysis Enhancements N-C10 to N-C25 Alkanes Calibration Sample

Chromatogram Incorporating Resistively Heated Column vs. GC Oven



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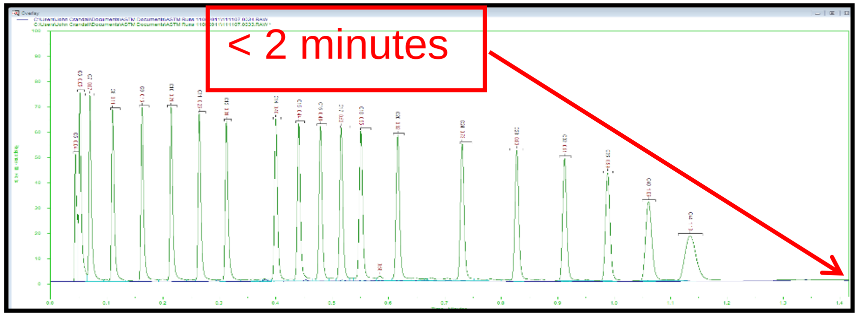
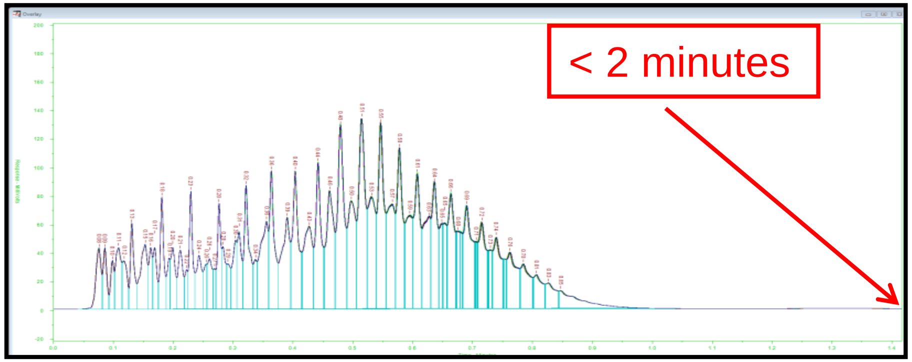
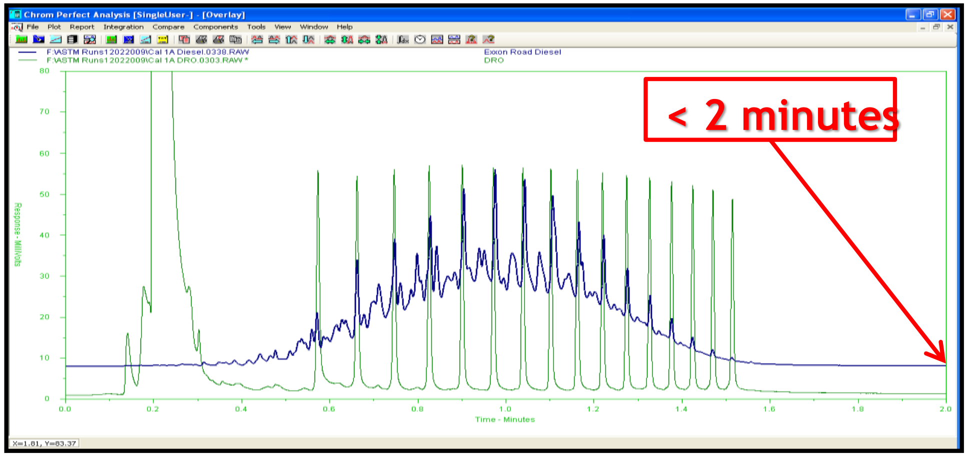
Examples of Analysis Enhancements



n-C_5 to n-C_{44} Retention Time/Boiling Point Std.



Gas Oil SASTM Reference Standard



ExxonMobil Road Diesel Overlaid RT/BP Standard

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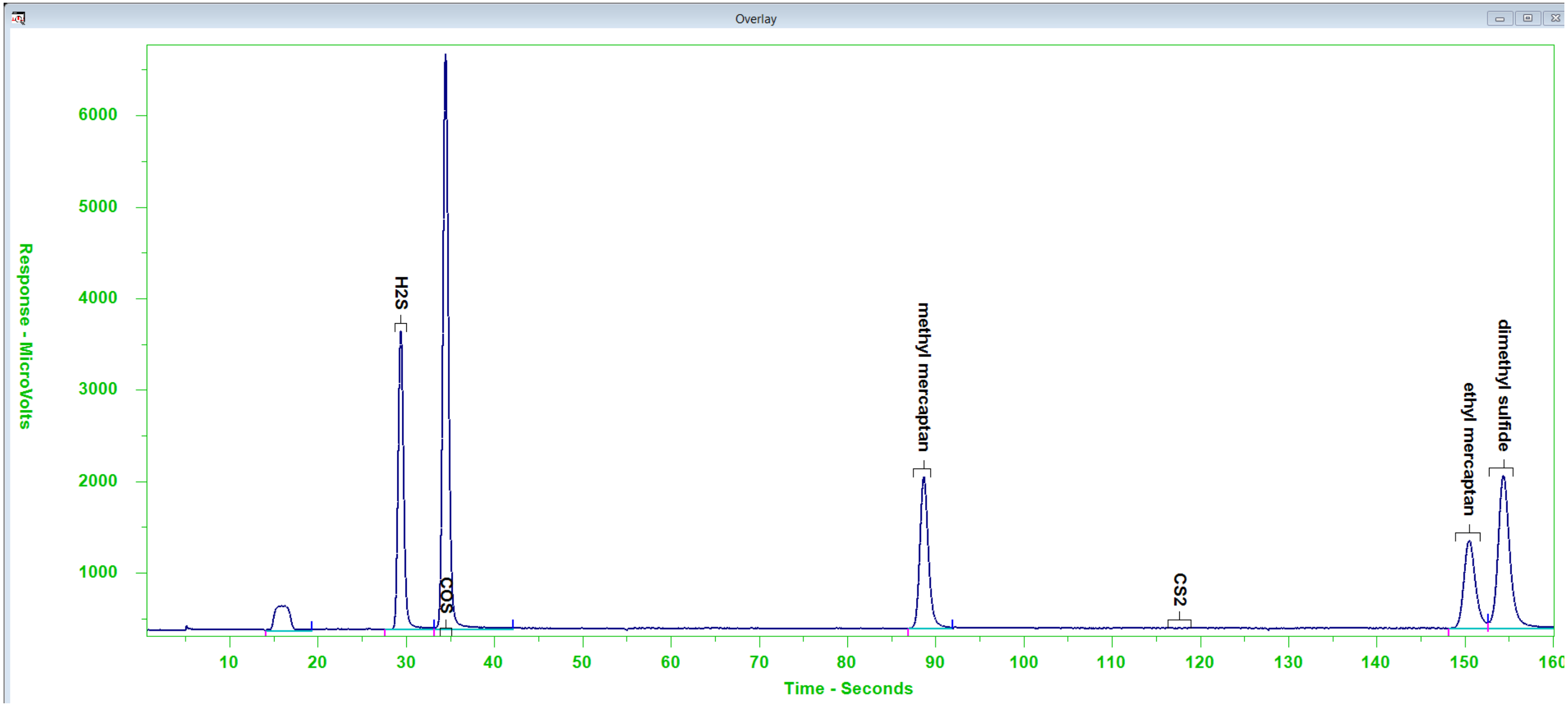
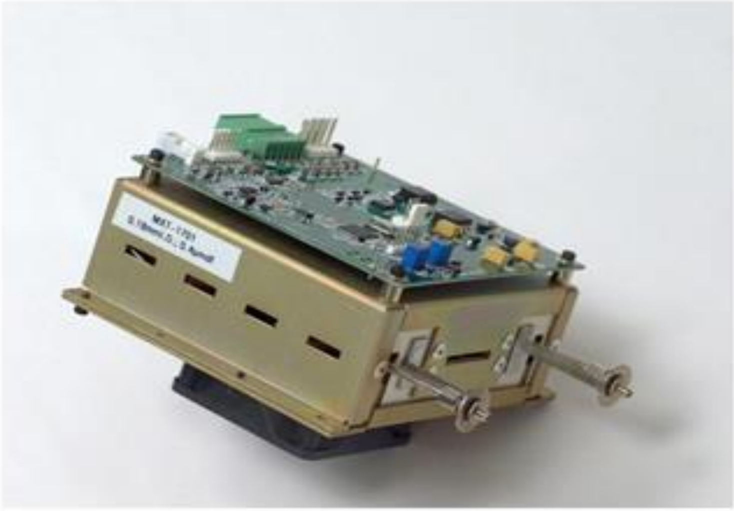
Examples of Analysis Enhancements

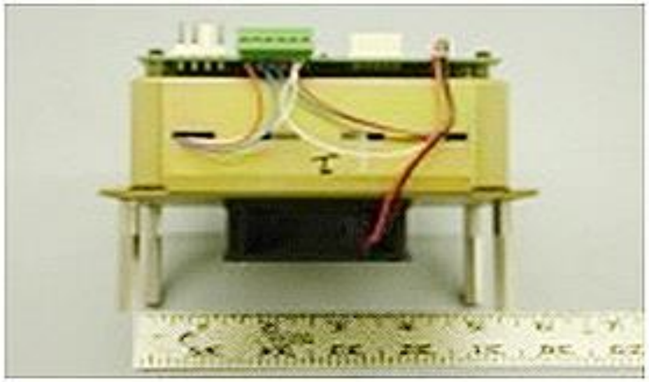
1 ppm each H_2S, COS, methyl & ethyl mercaptan and dimethyl sulfide in 160 seconds



Example of Modularity - Column Module with Temp Control ICs

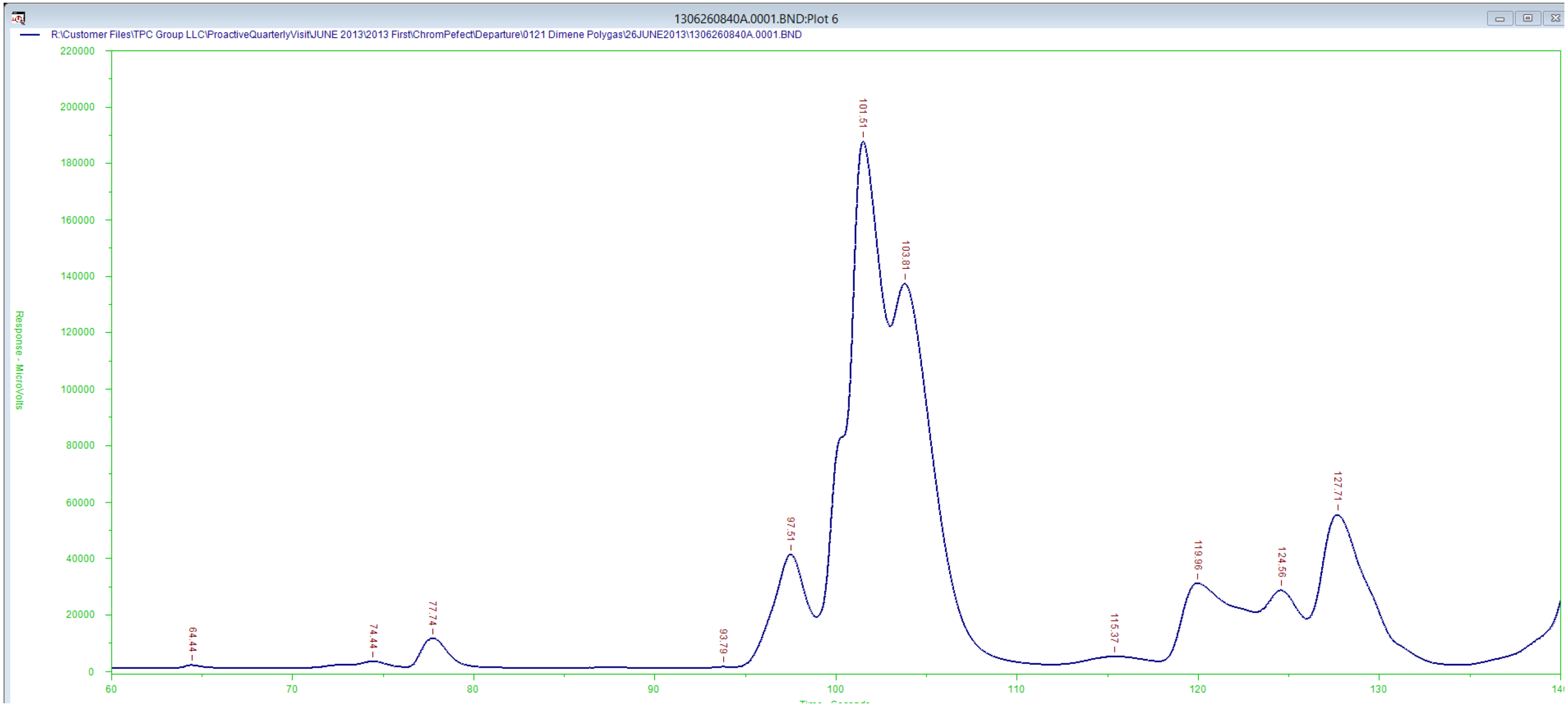
Column Module





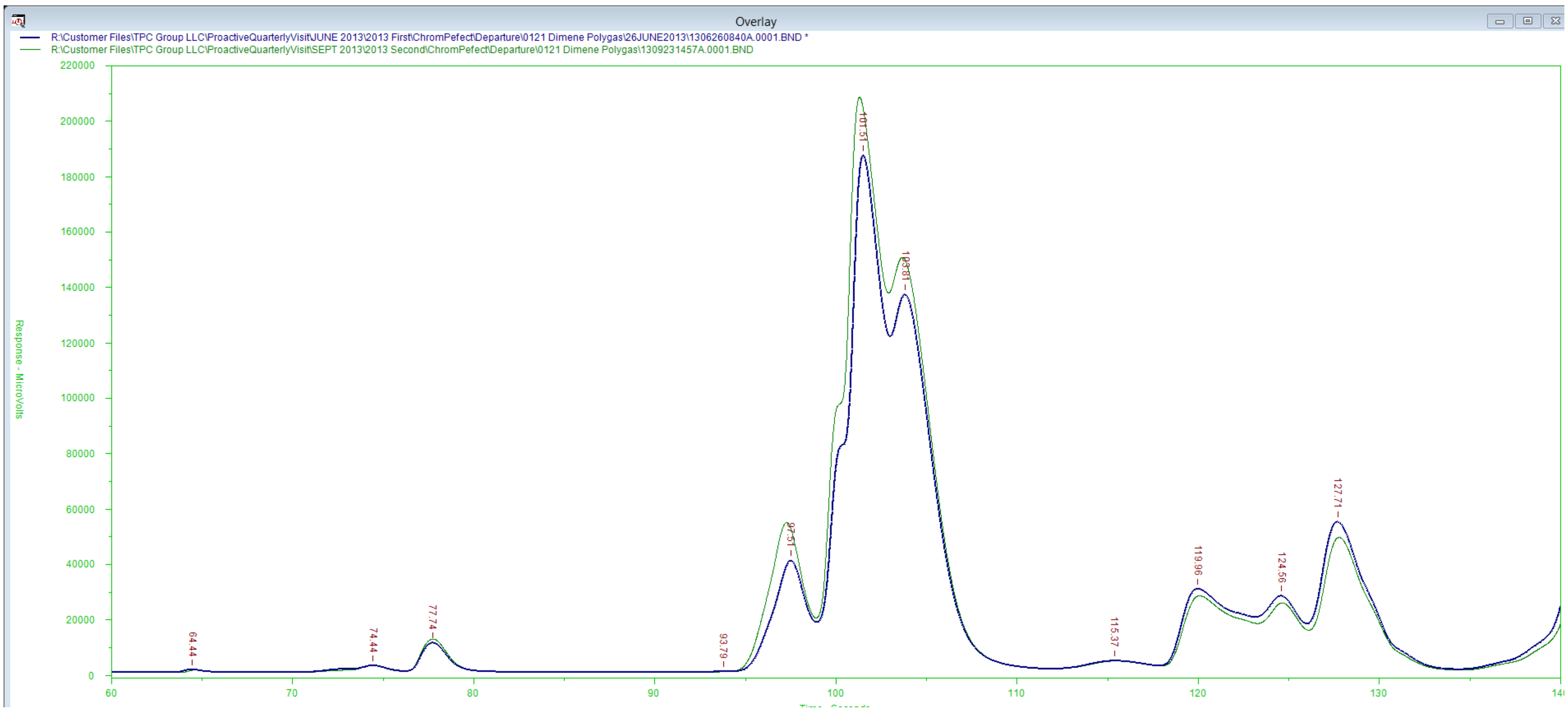
But What about Stability?

Q1 Visit: part of last run showing 60 to 140 seconds – Retention time alignment by Infometrix LineUp implemented – dimer, trimer & tetramers of olefinics



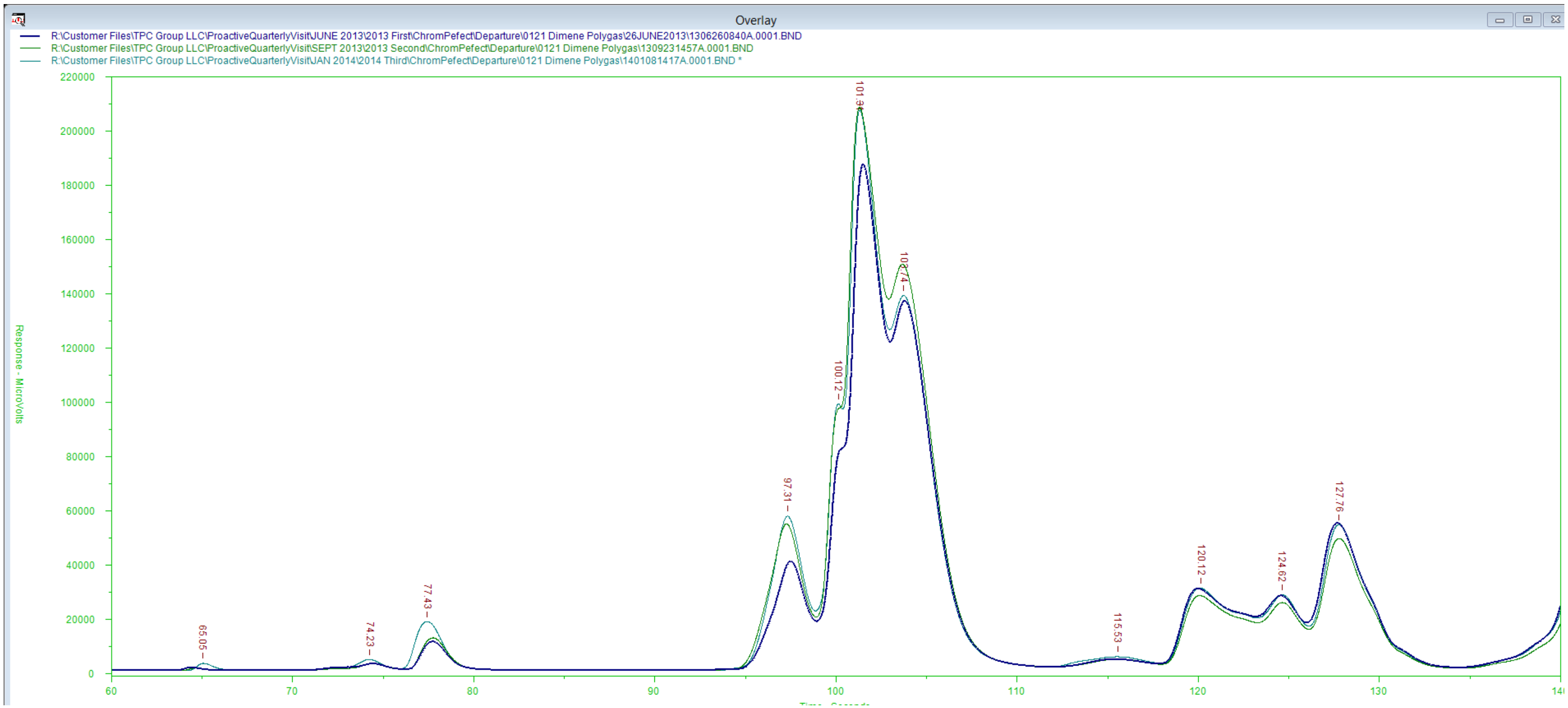
But What about Stability?

Q1 & 2 Visits Overlaid: part of last run showing 60 to 140 seconds



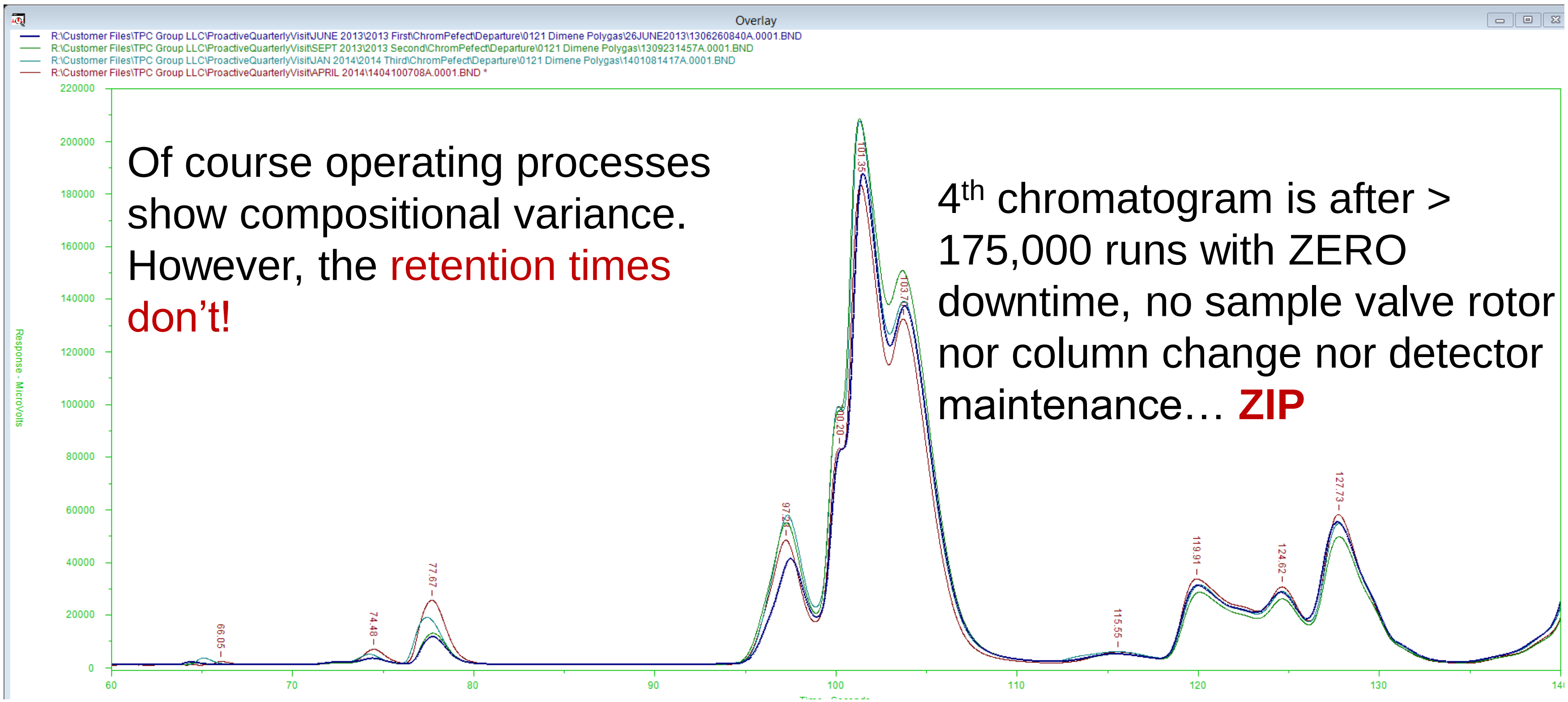
But What about Stability?

Q1, 2 & 3 Visits Overlaid: part of last run showing 60 to 140 seconds



But What about Stability?

Q1, 2, 3 & 4 Visits Overlaid: part of last run showing 60 to 140 seconds



Of course operating processes show compositional variance. However, the retention times don't!

4th chromatogram is after > 175,000 runs with ZERO downtime, no sample valve rotor nor column change nor detector maintenance… **ZIP**

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Overcoming the Hurdles to Industry Acceptance

- *With so many benefits why hasn't direct heating of columns been widely adopted by the industry?*
  - *Column Materials*
  - *Computer Processing Speed*
  - *Analog vs. Digital Electronics*
  - *Product Life Cycles*
  - *User Reluctance*
- *Direct heating of columns was first applied around 1985*

Column Materials

- Early Capillary Columns Were Made of Brittle Metal or Glass
  - Not flexible
  - Could not accommodate large temperature swings
  - Difficult to manufacture
  - Very expensive

Computer Processing Speed

- 30 sec. analyses vs. 5 min. means processing 2,880 cycles vs. 288 cycles in a 24 hour period
  - Ten times the computer processing power is required
- 80's only had 6-bit processing power vs. today's 24-bit processing. Translates to 100 times the processing power

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Size of Electronics

- *80’s analog electronics, yielded much larger components*
- *90’s digital electronics enabled much smaller components*
- *Today we have integrated circuits, the size of a thumb nail and smaller*

Product Life Cycle

- First process GCs sold in 1957 had an industry average expected life cycle of 20 years.
- Second wave of replacements came in the 70's.
  - Before the direct, on-column heating technology advances described above had occurred
  - Widespread consideration of GC and GC component designs like those detailed in this paper would not even begin until the early 2000s

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User Reluctance

- *Product life cycle issues*
- *"If they're not broke and we're making money, run them until they can no longer be supported."*
- *Spare parts inventory*
- *Retraining cost and time*
- *Recoding process control algorithms*
- *We "love our current supplier"*

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Product Capability and Ruggedness

- *A full suite of detectors, columns, and sample introduction capabilities must be in place.*
- *A physically durable analyzer is also needed for more rugged online, at-line and field deployment.*

Summary and Conclusions

- *To really change the anatomy of process, lab and field GCs to meet today's requirements, a more revolutionary change had to occur.*
- *Most new products develop through design evolution – small incremental changes over time that result in product improvement.*
- *The entire analyzer needed to be redesigned from the ground up, developing and incorporating all the state-of-the-art direct column heating and modular component technology described herein to completely achieve this revolution.*

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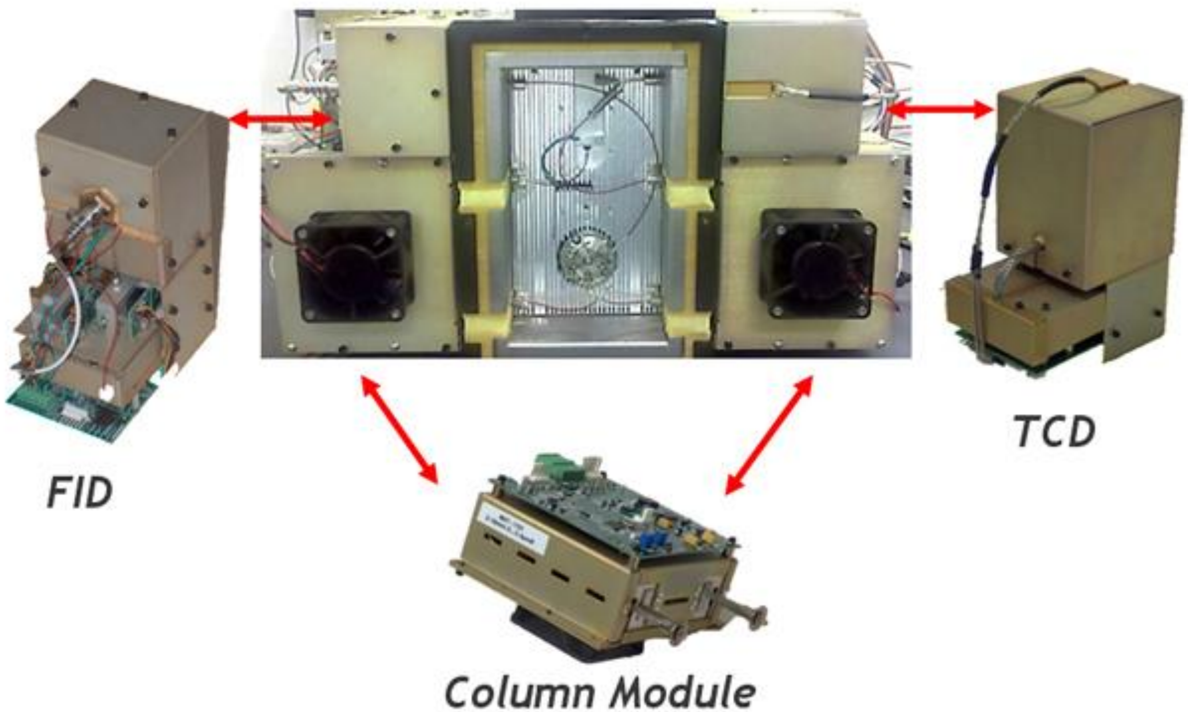
The Future of the Gas Chromatograph?

the Modular, Ultra-Compact GC



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Closing

- Questions and discussion
- Thank you for your interest

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