Ensuring analytical testing efficiency through modular gas chromatography

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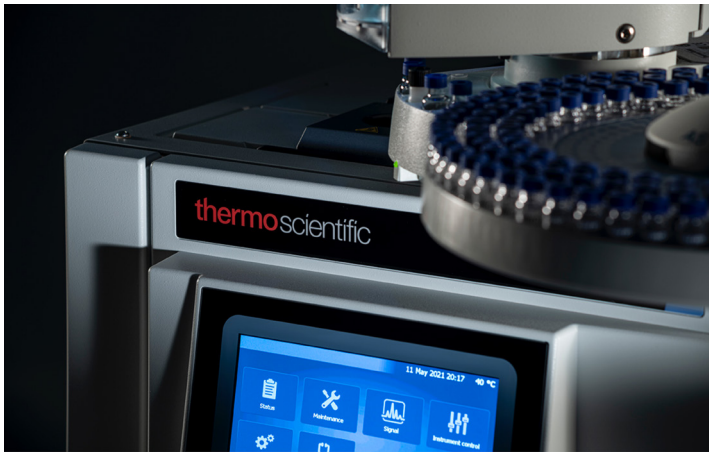


Scope

To highlight the modular design of the Thermo Scientific™ TRACE™ 1600 Series Gas Chromatograph (GC) and demonstrate the benefits offered to testing laboratories to increase their GC efficiency and productivity. Key benefits such as cost-saving and time-saving requirements will be covered with practical examples.

The revolutionary concept of modularity

Since the introduction in 2012 of the Thermo Scientific™ TRACE™ 1300 Series Gas Chromatograph (GC), there has been a growing market recognition of its innovative and unique modular design. It is all about user experience which, over the years, provided a comprehensive picture of the benefits offered by a modularity concept for analytical testing laboratories.

Analytical instrument manufacturers are responding to customers' expectations for a faster, easier, more productive analytical experience. The TRACE 1600 Series GC will continue to represent, through its modular design, a significant transformation to a more agile and smart approach to laboratory instrumentation.

The common design of a gas chromatograph, since the very first equipment introduced in the 1950s, is based on injectors and detectors bodies fully embedded in the top part of the GC mainframe to ensure optimal thermal insulation, connected to the pneumatic control in the back through dedicated plumbing for gas supply, and connected to the electronic boards through cables for temperature control and signal processing. Therefore, GC systems are typically factory-configured and any changes in configuration after the first installation, require expensive and time-consuming operations. This design, despite the fact it is in use for decades, may limit users in their analytical tasks. For example, maintenance procedures, as well as troubleshooting operations, can be time consuming and a service call is often required to operate

on the instrument for cleaning procedures or for parts replacement. Also, having GC instruments in the laboratory in fixed configurations, could prevent different analytical needs from being fulfilled in a short time. Additionally, laboratories which anticipate different analytical requirements in the future, may feel forced to invest more at the beginning in a fully-equipped system, to avoid the burden of upgrades in the future.

The TRACE 1600 Series GC continues the innovation legacy of the TRACE 1300 Series system by offering to the modern laboratories a design which embeds the injector and detector body, pneumatic control and electronic control board into handy modules, known as Instant Connect (iC) injector and detector modules. This design makes injectors and detectors available as tubing-free and cable-free independent sub-units of the instruments.

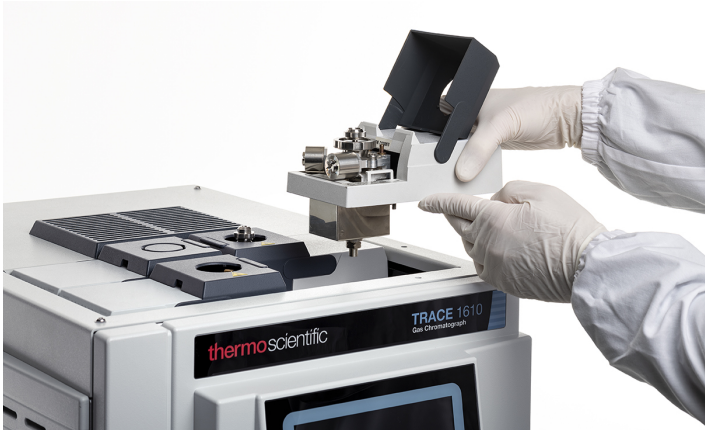


Figure 1. Plug and play concept for iC injector and detector modules

The iC injector and detector modules can be easily inserted in the dedicated slots on the top of the GC, thanks to a plug-and-play concept (Figure 1), permitting configuration changes in less than two minutes, with no need for expertise or special tools. To simplify this operation and get the system up and running immediately, every module is delivered tested and calibrated, so no additional setup is required after installation.

A wide range of iC modules are available to meet different application needs, including Split/Splitless (SSL) and Programmable Temperature Vaporizing (PTV) injectors, both in the standard and backflush configuration, Cold On Column (COC) injector, Gas Sampling Valve (GSV) with optional backflush and all standard GC detectors: Flame Ionization Detector (FID), Electron Capture Detector (ECD), Thermal Conductivity Detector (TCD), Nitrogen Phosphorous Detector (NPD), Flame Photoionization Detector (FPD) and Pulse Discharge Ionization Detector (PDD).

Performance consistency from module to module

Each module is identified by a serial number for easy tracking in the laboratory and can be qualified as a separate item, so to be safely interchanged on a GC instrument maintaining compliance with internal quality protocols.

All injector and detector modules incorporate a new generation of miniaturized gas controls. These integrated electronic devices ensure precise control of the inlet pressure and flow throughout the column, further contributing to the excellent repeatability and reproducibility of retention times. As indicated in Table 1, the standard

Table 1. Hydrocarbons retention time standard deviation in the range of 1/1000 minute

Run	n-C10	n-C12	n-C14	n-C16	n-C18	n-C20	n-C22	n-C24	n-C26	n-C28	n-C30	n-C32	n-C34	n-C36	n-C38	n-C40
1	2.562	3.935	5.253	6.445	7.525	8.506	9.408	10.237	11.005	11.717	12.385	13.010	13.598	14.153	14.680	15.190
2	2.562	3.933	5.252	6.445	7.525	8.508	9.408	10.237	11.005	11.718	12.385	13.010	13.598	14.153	14.678	15.188
3	2.562	3.933	5.252	6.445	7.523	8.505	9.407	10.233	11.003	11.715	12.383	13.007	13.597	14.152	14.680	15.189
4	2.562	3.935	5.253	6.445	7.525	8.508	9.408	10.237	11.005	11.718	12.385	13.008	13.598	14.152	14.678	15.188
5	2.562	3.933	5.252	6.445	7.525	8.508	9.408	10.237	11.003	11.717	12.385	13.010	13.600	14.154	14.678	15.191
6	2.562	3.933	5.252	6.445	7.525	8.508	9.408	10.237	11.005	11.717	12.385	13.010	13.598	14.153	14.680	15.189
7	2.562	3.933	5.252	6.447	7.525	8.507	9.407	10.237	11.003	11.718	12.385	13.008	13.597	14.153	14.681	15.190
8	2.562	3.933	5.252	6.445	7.525	8.507	9.408	10.235	11.003	11.717	12.385	13.008	13.598	14.150	14.680	15.190
9	2.560	3.932	5.250	6.443	7.523	8.506	9.408	10.235	11.002	11.717	12.385	13.008	13.597	14.153	14.682	15.191
10	2.562	3.933	5.252	6.445	7.525	8.508	9.408	10.237	11.005	11.718	12.385	13.010	13.597	14.152	14.682	15.188
Avg (min)	2.562	3.934	5.252	6.445	7.525	8.507	9.408	10.236	11.004	11.717	12.385	13.009	13.598	14.153	14.680	15.190
SD	0.0005	0.0009	0.0009	0.0008	0.0007	0.0012	0.0007	0.0012	0.0012	0.0011	0.0005	0.0012	0.0011	0.0012	0.0013	0.0010
RSD %	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.007%	0.01%	0.01%	0.01%	0.004%	0.01%	0.01%	0.01%	0.01%	0.01%

deviation of the retention times for a hydrocarbons mixture from n-C10 to n-C40 is below a thousandth of a minute. This level of repeatability is a clear indication of the accurate temperature profile and column flow maintained during the GC oven temperature ramp, with highly precise thermal regulation.

In addition to the performance of a single injector/detector module, the modularity concept requires analytical reproducibility and accuracy between modules of the same type to ensure consistency of the results after swapping.

The replacement of a module requires cooling and powering down the instrument, disconnecting the column from the module, removing the module and plugging in the new one, re-connecting the column, and powering up the GC again. The electronic gas control permits an automated leak check to guarantee no artifacts are introduced by this manual operation. All the above steps are achieved very easily in few minutes. The Thermo Scientific™ iConnect Column Lock (Figure 2) facilitates the column connection and disconnection in seconds, safely and with no tools required.

The reduced thermal mass design of the TRACE 1600 GC allows a quick recovery of injection-ready conditions after instrument power-up allowing to resume analytical injections in only nine minutes. A good practice is to run a quick blank GC cycle before injecting samples again to ensure the entire flow path is not affected by air introduced during module replacement.

Tables 2 and 3 show the module-to-module reproducibility in terms of peak areas and retention times over 10 repetitions before and after the replacement of an iC SSL injector and an iC FID detector.

Variations in peak areas of a hydrocarbons mixture, measured as a delta of the average counts, are in the range of a few percentages when changing either the SSL injector or the FID detector. Such a variation, for most applications, is well below the required limit of a system suitability check, eliminating the need to recalibrate the GC system. The retention time variations are in the range of a few hundredths of a minute or even less, with no impact on components identification.

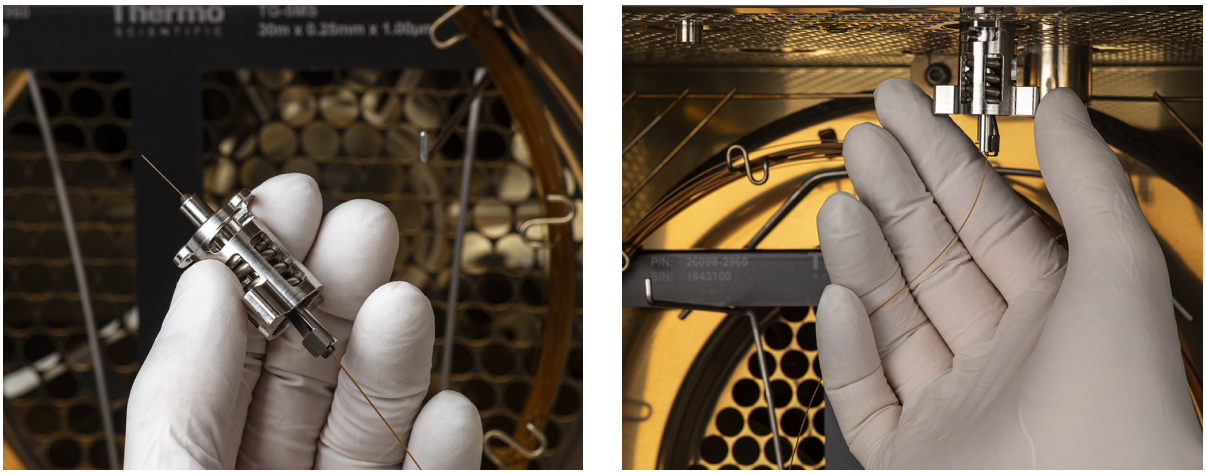


Figure 2. iConnect Column Lock allows quick, easy and safe column installation

Table 2. Variation in peak area as effect of module swap. All variations are in the range of few % changing either the inlet or the detector

Starting instrument configuration: SSL s/n 712100036 and FID s/n 712300088																
	n-C10	n-C12	n-C14	n-C16	n-C18	n-C20	n-C22	n-C24	n-C26	n-C28	n-C30	n-C32	n-C34	n-C36	n-C38	n-C40
Avg (counts)	2620726	2666702	2615432	2636561	2573604	2588848	2574011	2569231	2549064	2564570	2637520	2631510	2559913	2593130	2492829	2552320
SD	12355	10941	11571	11889	12894	12092	15913	14767	15078	15223	14298	13319	11161	13430	12358	13908
RSD %	0.47%	0.41%	0.44%	0.45%	0.50%	0.47%	0.62%	0.57%	0.59%	0.59%	0.54%	0.51%	0.44%	0.52%	0.50%	0.54%
Replacement of SSL module																
Avg (counts)	2705439	2722254	2654680	2680682	2615418	2647035	2626550	2624551	2604909	2618663	2699958	2707570	2658013	2713142	2598635	2604178
SD	8276	7559	8759	9119	11059	11146	12635	14822	13711	16916	16529	17096	12977	10030	12448	10215
RSD %	0.31%	0.28%	0.33%	0.34%	0.42%	0.42%	0.48%	0.56%	0.53%	0.65%	0.61%	0.63%	0.49%	0.37%	0.48%	0.39%
Variation %	-3.2%	-2.1%	-1.5%	-1.7%	-1.6%	-2.2%	-2.0%	-2.2%	-2.2%	-2.4%	-2.4%	-2.9%	-3.8%	-4.6%	-4.2%	-2.0%
Replacement of FID module																
Avg (counts)	2752208	2777431	2705697	2728377	2668020	2699389	2678126	2670723	2649792	2665081	2745907	2757795	2703327	2763143	2653118	2666225
SD	13455	15147	15120	11600	15162	14201	15885	15954	14781	15601	11514	14864	10635	13223	15755	11218
RSD %	0.49%	0.55%	0.56%	0.43%	0.57%	0.53%	0.59%	0.60%	0.56%	0.59%	0.42%	0.54%	0.39%	0.48%	0.59%	0.42%
Variation %	-1.7%	-2.0%	-1.9%	-1.8%	-2.0%	-2.0%	-2.0%	-1.8%	-1.7%	-1.8%	-1.7%	-1.9%	-1.7%	-1.8%	-2.1%	-2.4%

Table 3. Variation in retention time as effect of module swap. All variations are in the range of 1/100 of a minute or less, changing either the inlet or the detector

Starting instrument configuration: SSL s/n 712100036 and FID s/n 712300088																
	n-C10	n-C12	n-C14	n-C16	n-C18	n-C20	n-C22	n-C24	n-C26	n-C28	n-C30	n-C32	n-C34	n-C36	n-C38	n-C40
Avg (min)	2.562	3.934	5.252	6.445	7.525	8.507	9.408	10.236	11.004	11.717	12.385	13.009	13.598	14.153	14.680	15.190
SD	0.0005	0.0009	0.0009	0.0008	0.0007	0.0012	0.0007	0.0012	0.0012	0.0011	0.0005	0.0012	0.0011	0.0012	0.0013	0.0010
RSD %	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%	0.007%	0.01%	0.01%	0.01%	0.004%	0.01%	0.01%	0.01%	0.01%	0.01%
Replacement of SSL module																
Avg (min)	2.566	3.938	5.255	6.448	7.527	8.509	9.410	10.238	11.005	11.719	12.386	13.011	13.599	14.154	14.679	15.188
SD	0.0006	0.0012	0.0007	0.0004	0.0009	0.0007	0.0007	0.0014	0.0007	0.0015	0.0009	0.0015	0.0009	0.0014	0.0015	0.0014
RSD %	0.02%	0.03%	0.01%	0.006%	0.01%	0.01%	0.007%	0.01%	0.006%	0.01%	0.007%	0.01%	0.007%	0.01%	0.01%	0.01%
Variation %	-0.2%	-0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Replacement of FID module																
Avg (min)	2.563	3.935	5.254	6.446	7.525	8.508	9.408	10.237	11.004	11.718	12.384	13.011	13.598	14.154	14.679	15.186
SD	0.0007	0.0007	0.0010	0.0007	0.0014	0.0008	0.0009	0.0014	0.0010	0.0009	0.0009	0.0010	0.0018	0.0007	0.0014	0.0019
RSD %	0.03%	0.02%	0.02%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.008%	0.007%	0.01%	0.01%	0.005%	0.01%	0.01%
Variation %	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Robust analytical performance

The operation of connecting and disconnecting a module is robust, even after hundreds of replacement cycles, producing consistent results. No GC experience is required to swap a module.

Module robustness was tested mechanically by having ten different operators with different GC expertise repeatedly insert and remove an SSL injector module. The sequence applied by each operator included powering off the GC, removing the module, inserting the module, and powering up the GC until it reached ready condition. Each operator repeated this cycle ten times. After each cycle, the column was re-connected to the SSL injector and FID detector, followed by a double blank run. Ten automated injections of the hydrocarbons mixture completed the test.

Tables 4 and 5 show the negligible variation of absolute peak areas (< 1.08%) and retention time (< 0.04%) for the hydrocarbons mixture before and after replacing the SSL module 100 times.

Table 4. Variation in peak area before and after 100 times module replacement cycle

	n-C10	n-C12	n-C14	n-C16	n-C18	n-C20	n-C22	n-C24	n-C26	n-C28	n-C30	n-C32	n-C34	n-C36	n-C38	n-C40
Run 9 before swap	2754987	2779540	2709468	2720590	2662466	2694642	2671418	2666034	2640542	2660383	2748956	2756412	2705301	2768808	2658421	2670870
Run 10 before swap	2751265	2775027	2708032	2732281	2677453	2705799	2688053	2684329	2667261	2684684	2755387	2771243	2709754	2772642	2651536	2665536
Run 1 after swap	2767372	2791927	2719553	2738439	2664499	2693367	2672357	2657758	2643338	2655810	2738028	2745997	2704789	2768416	2664390	2670998
Run 2 after swap	2756768	2787601	2711585	2738364	2687682	2720242	2699762	2690563	2663741	2677520	2756966	2774421	2711745	2765971	2664631	2676359
Variation	-0.59%	-0.61%	-0.43%	-0.23%	0.48%	0.46%	0.58%	0.99%	0.90%	1.08%	0.63%	0.91%	0.18%	0.15%	-0.48%	-020%

Table 5. Variation in retention time before and after 100 times module replacement cycle

	n-C10	n-C12	n-C14	n-C16	n-C18	n-C20	n-C22	n-C24	n-C26	n-C28	n-C30	n-C32	n-C34	n-C36	n-C38	n-C40
Run 9 before swap	2.562	3.935	5.253	6.447	7.525	8.507	9.408	10.235	11.003	11.717	12.383	13.010	13.598	14.153	14.678	15.185
Run 10 before swap	2.563	3.933	5.255	6.445	7.523	8.508	9.407	10.237	11.005	11.717	12.383	13.012	13.595	14.154	14.677	15.185
Run 1 after swap	2.563	3.935	5.253	6.447	7.525	8.507	9.408	10.238	11.003	11.718	12.385	13.010	13.598	14.153	14.678	15.183
Run 2 after swap	2.563	3.935	5.253	6.447	7.523	8.508	9.407	10.237	11.003	11.718	12.385	13.012	13.600	14.155	14.680	15.187
Variation	-0.03%	-0.04%	0.04%	-0.03%	-0.02%	0.01%	-0.02%	-0.02%	0.02%	-0.01%	-0.01%	0.02%	-0.02%	0.00%	-0.01%	0.01%

Laboratory efficiency through modularity

Modular architecture can fundamentally transform the way laboratory technicians and managers use analytical technology, unlocking new saving opportunities while addressing both technical and business needs. Having the capability to easily and quickly install and uninstall injectors and detectors and having spare iC modules on hand for fast replacement, can eliminate the need for maintaining a duplicate GC back-up instrument, which optimizes valuable bench space and reduces cost of operation.

Alternative approaches with off-line maintenance and cleaning procedures are possible, keeping the GC system up and running and minimizing instrument downtime. The module replacement is so fast, simple and secure that it does not require service support, resulting in a significant time and cost saving. Figure 3 is showing an example of minimized downtime and cost saving during a problem-solving workflow due to Electronic Pressure Control (EPC) contamination.

On a conventional GC, if a problem with an injector is identified, performing maintenance is the first step and deeper cleaning can take several hours. In some cases, this may not solve the issue, requiring a service call with additional time and cost.

With a TRACE 1600 Series GC, replacement of the injector module and the ability to perform all maintenance procedures off-line (deep cleaning, consumables replacement and conditioning), limits the intervention to less than a half hour.

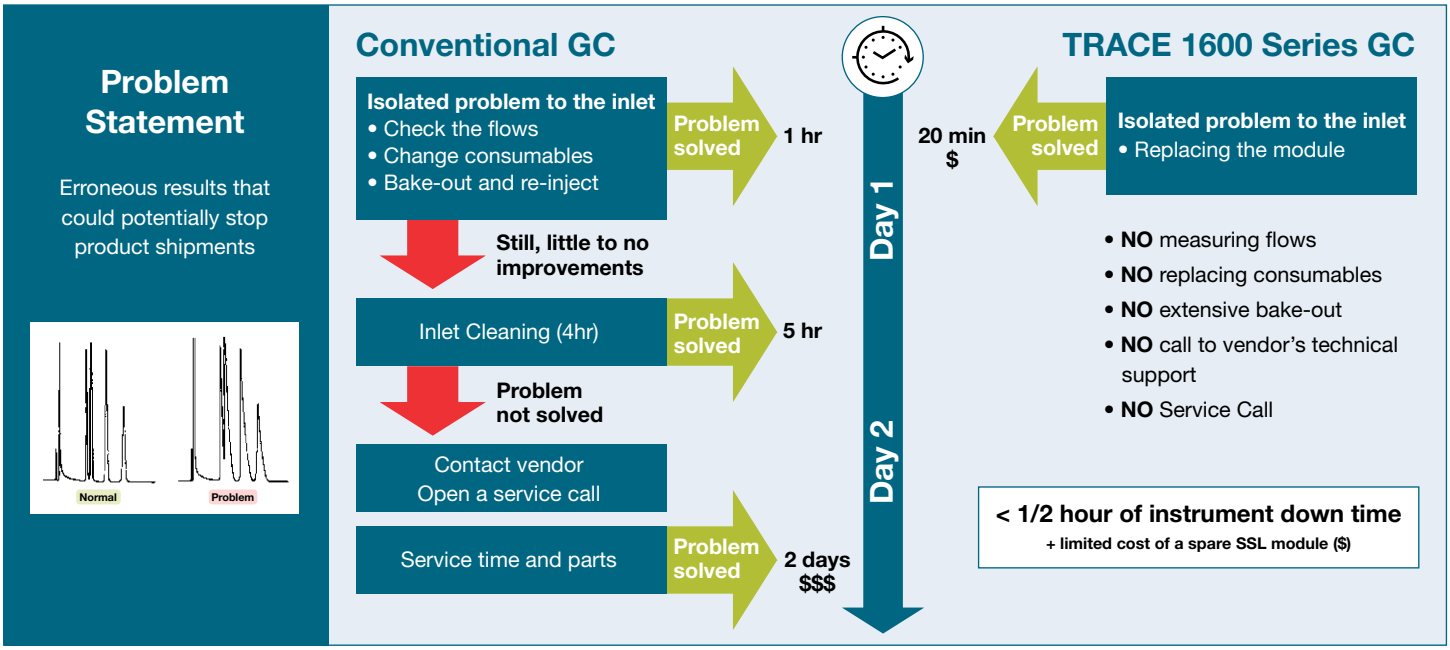


Figure 3. Example of downtime and cost saving with the modular TRACE 1600 Series GC

Modularity drives online purchase and service delivery

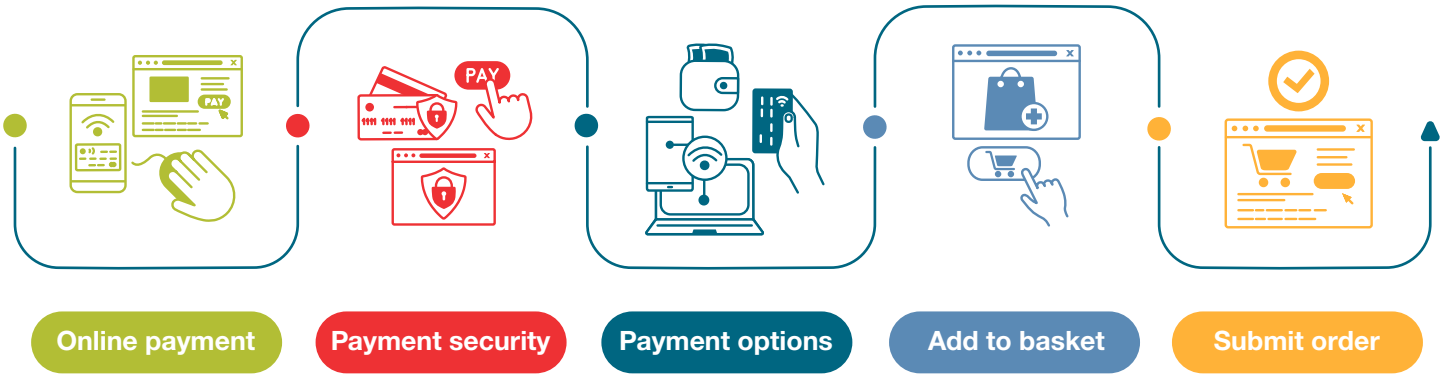
Analytical testing laboratories need to deliver quality results on time, every time. Often, in a situation where a laboratory needs to quickly recover a correct analytical response, the module replacement may restore the instrument running condition in less than 30 minutes, including cooling and powering down the instrument and powering up the GC again. The same operation on a conventional GC design would require a service call and a working day of instrument downtime. In fact, when a spare module is available, time-consuming troubleshooting actions are skipped and service calls avoided, reducing instrument downtime to minutes.

Modularity offers additional benefits in terms of procurement. If spare modules are not readily available in the laboratory, online purchasing* of modules and other consumables with guaranteed delivery in 24 hours is possible through thermofisher.com/tracegc. In addition to fast delivery, users can track orders, access stock information and receive online technical support.

Modularity enables flexibility

In many cases as for start-up and academic laboratories, investments need to be prioritized by purchasing capital equipment that fits for the needs of the analyses without overspending on budget. A very common situation

*For eCommerce eligible Countries contact your local sales representative



is that while short term requirements are clear, future requirements remain unclear, and the same GC might be needed in the future for different applications. Therefore, it is challenging to make the best choice for addressing evolving analytical needs with an initial investment. With a conventional GC, saving money today may lead to higher costs in the future. Modularity offers the opportunity to invest based on current requirements but leaving the ability to change configuration for different analytical needs or scale up for increased workload without expensive instrument upgrades or additional instrument purchase which is more costly and often challenging when laboratory space is limited.

Figure 4. Flexibility to share modules within different GC systems

Flexibility drives quicker return on investment

The innovative modular concept of unlimited GC configurations and the ability to share modules on any Thermo Scientific TRACE 1300 and 1600 Series GC (Figure 4), multiplies the analytical possibilities. With the increased flexibility gained from modularity, an instrument no longer needs to remain idle because it's not configured to run particular sample types. More efficient use of your laboratory instruments accelerates the return on investment.

Conclusion

The TRACE 1300 and 1600 Series GC offers unique advantages over GC instrumentation with a conventional design, helping laboratories to maximize operational efficiency and optimize costs and investments.

Thanks to the modular design, the TRACE GC instrument's configuration can be easily adapted with handy iC injector and detector modules, which incorporate all mechanical and electronic components with calibration information. Readily available through online purchasing and 1-day delivery, iC modules allow the analyst to rapidly swap injectors or detectors, without any service assistance, when needed.

The results described in this product spotlight demonstrate outstanding module-to-module reproducibility within 5% of the variances in absolute peak area and consistent retention times. The robust design enables the modules to be replaced without impacting instrument or method performance, even after hundreds replacements.

The modular design unlocks several time and cost savings opportunities through off-line maintenance capabilities, simplified troubleshooting and the flexibility to quickly adapt the GC to different analytical needs in a cost effective way, all supporting the increase of a laboratory's productivity.

Find out more at **thermofisher.com/tracegc**

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