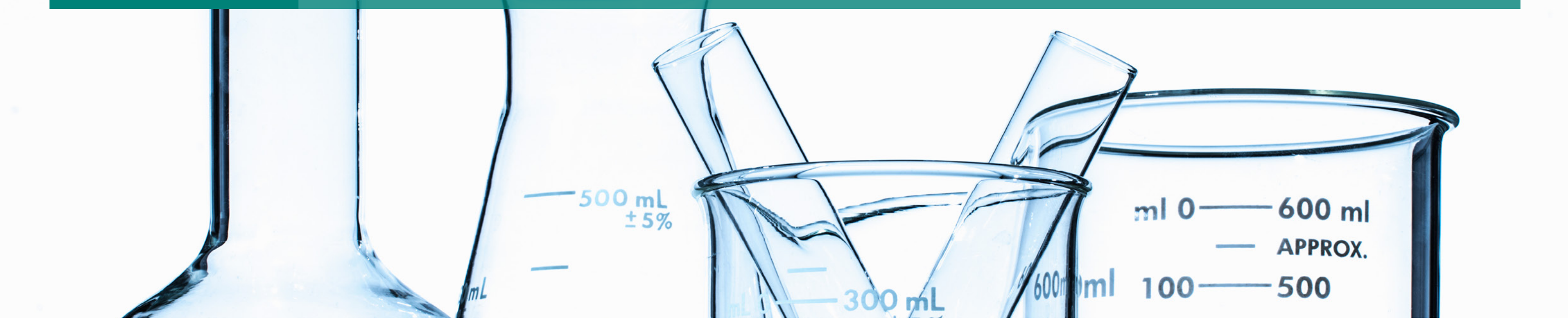
ARTICLE

Simplifying the GC Laboratory for Improved Efficiency



Introduction

Gas chromatography (GC) is one of today's most versatile and widely used analytical techniques. It is found in the laboratories of chemical, petrochemical, and pharmaceutical facilities, quality control labs that analyze environmental, food, and beverage samples, research labs, and many others.

Laboratories rely on GC to separate and analyze compounds present in solids, liquids, and other sample media in order to determine their sample makeup, quality, and purity. Those characteristics can have significant impact on product performance, human health, and the environment. For this reason, many companies must confirm that their products meet industry or regulatory standards.

Laboratory managers have the responsibility of ensuring their staff are fully trained in the proper protocols and best practices for sample preparation and handling, workflow optimization, and generation of audit-compliant data and documentation. Even under the best of circumstances, however, labs are still vulnerable to human error. Reducing complexity in the lab can help minimize the opportunities for error.

Simplification is one of the strategies of Industry 4.0 for manufacturing processes. It can also be applied to laboratory operations where it will support lab managers in their efforts to minimize human error and drive business excellence. This article discusses how adoption of Industry 4.0 simplification strategies can drive excellence in GC laboratory operations, and demonstrates how PerkinElmer is helping lab managers drive the Laboratory 4.0 transformation.

Industry 4.0

Industry 4.0 era: a new way of production sustained by digitalization by means of smart and autonomous systems fueled by data and machine learning.

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Figure 1. Main steps of a typical GC or GC/MS workflow.

Sample Preparation

GC instrumentation has evolved greatly over the past few decades making it much easier to use and more reliable. As a result, throughput rates have increased and, in turn, put pressure on upstream and downstream portions of the GC workflow to keep up with the pace.

Figure 2. Typical steps of sample preparation process.

Upstream sample preparation is still the most time-consuming and error-prone part of the GC workflow. Even so, the versatility of GC makes it challenging to define a standard sample preparation process for the many different sample types that can be analyzed.

For example, sample preparation needs vary based on the level of sensitivity required and the makeup of the material sample. A sample might contain unexpected contaminants or unstable components such that it requires additional processing before it can be injected into the GC column.

Another challenge in GC sample processing is preventing escape of volatile organic compounds (VOCs) from the sample before it is injected to the GC. Many VOCs can evaporate or sublimate from samples at room temperature, and all will vaporize when the sample is heated. Sample acquisition and sample preparation techniques must be designed to limit VOC loss from initial collection to GC analysis.

Simplification of GC sample prep and handling can take different forms. In a manual process, steps can be eliminated or combined in some cases, and use of a closed system wherever possible reduces VOC losses. More advanced alternatives are to migrate the manual process to a semi-automated or fully-automated approach.

Automation is the preferred option due to the improvements it provides in productivity, data quality, and error prevention. Instruments are available today that can automate sample preparation steps including dilutions, derivatizations, internal standard addition, and more. Autosamplers are available that can collect and transfer liquid and headspace gas samples for injection to the GC.

Headspace sampling involves separating volatile compounds from the rest of the sample matrix before introducing it to the GC. This separation is important when a sample may contain less-volatile compounds that are not appropriate for GC analysis because of their potential to react with the column's stationary phase or otherwise contaminate column. Thus, headspace sampling provides a much cleaner, easier, and faster GC run. A headspace sampling system automates this process by extracting a small volume of headspace vapor from the vial and transferring it to the GC column.

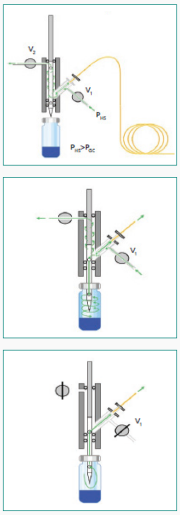
For example, the PerkinElmer HS 2400™ Headspace Autosampler, powered by pressure balanced sampling technology, introduces samples into the GC column without the use of a gas syringe or valve and loop, thereby overcoming potential VOC losses inherent in manual processes. This automated process also eliminates sample interactions on metallic surfaces, thus removing the risk of condensation in the loading syringe. The result includes sharper peaks, exceptional reproducibility, and more accurate results.

Pressure balanced Sampling Technology

Pressure balanced sampling technology provides direct injection of headspace gas from the sample vial to the GC column through a closed-loop system. First, the sample vial is incubated until liquid/headspace equilibrium is reached. A needle is then inserted into the vial's headspace and the system is pressurized with a carrier gas. The system flow valve is opened for a specified length of time, allowing a specific volume of headspace gas from the vial to directly flow into the CG column.

This technique eliminates the need for sampling syringes, sampling ports, and other moving parts, and avoids sample contact with hot metal loops. The simplified system minimizes potential sample loss via leaks or areas of dead volume. The result is greatly improved reproducibility of the workflow and precision of results.

Pressure balanced sampling technology



Standby

The heated needle area is constantly flushed with carrier gas to remove contamination. Because the column or transfer line is inserted all the way to the needle, maximum inertness and minimal dead volume are maintained.

Pressurization

All vials are pressurized to the exact same degree. Optimal reproducibility and precision are achieved regardless of equilibration pressure in the vial.

Sampling

A solenoid valve interrupts the carrier gas flow and the vial acts as a reservoir of carrier gas. During injection, as the pressure decays, sample volume is transferred to the column. This prevents carrier gas from diluting the sample and avoids expansion of the sample before injection.

Figure 3. Pressure balanced sampling technology.

Laboratories that handle many different types of GC samples need the ability to integrate and exchange different components of the workflow. The software-driven GC 2400 Platform supports workflow changes with self-configuration and self-recognition capabilities that eliminate the need for manual intervention during workflow modifications. For example, the PerkinElmer AS 2400™ Liquid Sampler is plug-and-play and readily interchangeable on multiple GC 2400 systems. Its adaptability is especially important for labs that are very mindful of capital investment and need a timely return on investment.

Instrument control and Data collection

Simplifying the instrument control and data management of a GC workflow requires software that is easy to use yet adaptable and powerful. Optimally, a single software platform will be able to control hardware, automation, and data collection and management. It should also have an intuitive user interface that enhances workflow integration, hardware deployment, and collaboration.

Studies have shown that daily use of digital devices impacts cognitive behaviors, and evidence has been found that smart devices are used to supplant thinking. These findings need to be taken into consideration by laboratory managers as their staff begin interacting with advanced software and analytical instrumentation. For these reasons, the user interface and user experience (UI/UX) play an important role in simplifying analytical workflows and promoting the implementation of Industry 4.0 features in the lab. UI/UX are helping to simplify how technology is adopted by final users. Furthermore, UI/UX are filling or eliminating gaps at the user level by easing the need for specialized skills and minimizing training needs.

With its iconographic style, the PerkinElmer SimplicityChrom™ Chromatography Data System (CDS) Software provides intuitive instrument control and data management of the GC 2400 Platform. The platform's detachable touchscreen and web app allow users to access the workflow from any location within the lab and beyond. This powerful combination means that users can monitor in real-time the status of instruments within the integrated workflow. In addition, live updates and notifications help monitor instrument performance and the progress of sample runs.

Data acquisition, processing, and reporting are also easy and adaptable with the GC 2400 Platform. For example, different data tables and chromatograms can be selected and viewed for specific analytes across multiple samples, enabling the identification of trends and better data analysis.

Instrument Maintenance

Simplification of lab operations for GC and GC-MS can't exclude consideration on maintenance.

Caring for and maintaining GC instrumentation is to be considered a key element of lab quality assurance in the lab. Without well-maintained equipment, productivity and integrity are endangered, because data fails to be consistent and reliable. Not only does well-maintained lab equipment impact data, but it contributes to business sustainability of the lab, mitigating the risks of premature repurchases and replacement[3]. Furthermore, with maintenance processes established in the lab, staff can work in safety, while focusing on the analysis outcome.

The challenge for labs is that maintenance can be time-consuming and sometimes it is necessary when it is too late. Various procedures and routines can help labs ensure that laboratory equipment is well-maintained and cared for:

- Developing standard operating procedures (SOPs) for all lab equipment: by being easily accessible at the workbench, SOPs ensure that the correct use and maintenance of the equipment is integrated within routine work.
- Develop SOPs for the preventive maintenance tasks that can be conducted regularly by instrument operators. Make the SOPs easily accessible at the workbench. Develop SOPs to help integrate proper equipment use and maintenance into overall lab operations.
- Develop an annual preventative maintenance schedule that will minimize workflow disruption and ensure all instruments get the attention needed throughout the year.
- Conduct initial and periodic staff training on the proper use and care of lab equipment. Include a review of the SOPs with hands-on demonstrations.

- Select instrumentation that has simplified maintenance processes. Simplified maintenance procedures should be on the list of criteria for evaluating a new instrument purchase.

New innovations in laboratory instrument design provide more streamlined maintenance processes. For example, the GC 2400 Platform includes features that help labs simplify instrument maintenance. The real-time status notifications, both on the portable touchscreen and the hardware itself (LEDs and sounds), automate and notify users of the system status, thereby accelerating the intervention decision-making process and reducing down-time.

Key Features for Maintenance

- SOPs
- Annual preventative maintenance schedule
- Periodic staff training
- Instrumentation with simplified maintenance processes

Maintenance simplification is also important for mass spectrometer (MS) users. The standard cleaning and service of the MS source starts by removing the source from the vacuum housing, followed by disassembly, cleaning and polishing, washing, and finally reassembly and testing. That is a very time-consuming process that is prone to human error. The PerkinElmer MS 2400™ SQ Detector features SMARTsource™ Technology (Simplified Maintenance and Removal Technology) which provides tool-free source access, cleaning, and maintenance. With SMARTsource Technology, labs will have greater instrument uptime and sample throughput.

Conclusion

Industry 4.0 is leading manufacturers toward process and system sophistication, and at the same time toward overall simplification and improved efficiency. Laboratories can also embrace Industry 4.0 strategies to increase their efficiency, data quality, and business sustainability. The PerkinElmer GC 2400 Platform can help laboratories simplify and enhance their GC workflows through automated, software-driven capabilities.

References

1. de Koning, S., Janssen, HG. & Brinkman, U.A.T. Modern Methods of Sample Preparation for GC Analysis. Chroma 69, 33 (2009). https://doi.org/10.1365/s10337-008-0937-3
2. Nathaniel Barr, Gordon Pennycook, Jennifer A. Stolz, Jonathan A. Fugelsang, The brain in your pocket: Evidence that Smartphones are used to supplant thinking, Computers in Human Behavior, Volume 48, 2015, Pages 473-480, ISSN 0747-5632, https://doi.org/10.1016/j.chb.2015.02.029
3. Powdrill S., Cordero I. and Srinivasan V. (2010). Training for equipment maintenance and repair. Community Eye Health. 23(73): 30–31.
4. Collaborative Robots Uses in Laboratories (automate.org)
5. Manufacturing Chemist. 2022. Three digital strategies to modernise quality control lab operations. https://manufacturingchemist.com/news/article_page/Three_digital_strategies_to_modernise_quality_control_lab_operations/198216

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