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Process gas chromatography: Avoid the iceberg of hidden expenses

Total cost of ownership can quickly add up for field analytical equipment

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Process gas chromatographs (GCs) are the most common multi-component, online chemical analyzer used in modern hydrocarbon processing industry (HPI) facilities—refineries, petrochemical plants and natural gas sites. GCs are proven and can provide data to control processes, supervise product quality and monitor facility emissions. Historically, GCs were placed in shelters that provided a stable temperature environment and a clean work area for operation and maintenance periods.

To ensure optimal performance and reduce sample lag time—the time required for a sample to travel from the sample tap to the GC—the shelters were often located in areas classified as hazardous by industry codes and standards. Also, the space for the GC and shelter was not always available in close proximity to the process line being sampled.

In both situations, significant costs were added to these projects that operations or environmental personnel had not considered in the project budget. The primary focus would have been on purchasing a GC that could provide a reliable and repeatable analysis of a sample stream at the best price. Unfortunately, the cost for the GC often represents a very low percentage of the total project cost, about 5% to 20%. Parties responsible for profit and loss (P/L) of operating units, plants and pipelines are keenly aware of the total cost impact of adding a traditional GC to perform a stream analysis. Accounting systems are now more open, and in-house engineering and installation resources have been replaced with contractors and consultants. So where are the "hidden" costs for field-mountable GCs, and what can be done to greatly reduce the total costs to install and operate a GC?

The iceberg. Selecting, installing, operating and maintaining a traditional GC can, and does, involve costs that exceed the capital cost for the GC. Think of the total cost structure as being similar to that of an iceberg in the ocean. A typical iceberg has about 10% to 15% of its volume above the water with the remainder hidden below the water's surface. When deciding to install a GC, think of the price for the GC (only) as the portion of an iceberg visible above the water. This example shows that significant additional costs may not be considered when selecting the GC. Those costs can include: a protective shelter, in-house or contracted engineering, installation charges, instrument air, heated sample lines, training, and startup and check out.

Shelter. If one assumes that the shelter will need to control

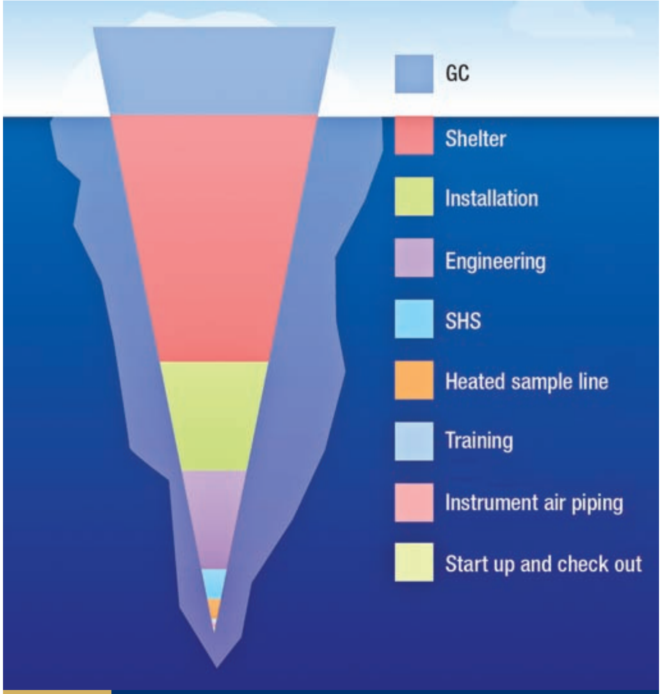

FIG. 1 Iceberg of hidden costs.

temperature in both directions—heating during winter and cooling during summer—and be compliant to hazardous ratings of the location, it will represent at least 40% of the total project cost. One cannot simply consider the cost of four walls, a door, a roof and a floor for a typical installation. The additional costs of the heating, ventilation and air conditioning (HVAC) unit also involve a purge system, area monitors and alarms, lighting, communication and electrical distribution, as well as instrument air, plumbing and vent headers; all must be considered.

Engineering. The cost for both in-house and contract engineering are significant for any project. They involve bringing a physical structure onto an industrial plant. These costs are somewhere between 15% to 18% of the total project cost.

At the onset, equipment requirements need to be understood and discussed by those wanting the new GC and those that are responsible for the processing unit that will house the GC. Specifications must be developed and distributed to internal teams and potential suppliers that address the installation area including hazards present, available footprint, environmental conditions, proximity to sample point and utilities, etc. After hundreds of hours of reviewing proposals, clarifying concerns and ultimately making a purchasing decision, site-preparation engineering must begin. Foundation requirements need to be detailed, plumbing and conduit runs drawn up, communication and power interconnections finalized. All actions require significant time and, therefore, add cost to the GC addition project.

Installation. Once the planning and designing are detailed, the shelter must be physically installed. Installation charges will make up 15% to 20% of the total GC project costs. The material and labor costs to install a secure base (concrete pad) represent a portion of the installation costs, but not all of it. If the shelter is large, the installation may require renting a large crane to place the shelter in the final mounting location—a significant additional expense. Even if the shelter can be placed at the selected location utilizing available plant equipment, labor costs will still be incurred as the structure is secured, communication and power interconnects are made, and tubing and piping are connected to existing points in the plant.

Instrument air. Although instrument air is often readily available in a plant, lines must be installed to the shelter, thus adding more costs to the project. These expenses are composed of not only materials, but also the labor required to install and connect the hardware. The operational cost of air use should also be considered. Using a cost of $0.80/1,000 scf for plant air, an air-bath-heated GC can add over $2,000 to the operational costs. If the GC and shelter also require purge system, the operating costs to escalate.

Heated sample line(s) and probe(s). For samples necessitating extended sample line runs (assume 200 ft = "extended") and a heated probe, it is reasonable to assume an additional cost of $7,000–$15,000 to total project expenses. Sample lines that are unheated and uninsulated can save several thousand dollars in costs, but one needs to closely evaluate the typical stream composition and its possible dew point and compare them to the known environmental conditions before foregoing heated sample lines. Failure to do so may result in multi-phase samples entering the sample-handling system or the GC, resulting in inaccurate analysis values.

These "hidden" costs account for 70% to 80% of the total installation cost of a new GC. They are referred to as "hidden" costs, as they are often not considered when the initial decision is made to add a control or required measurement in a plant. Obviously, they must be.

How can you reduce 'hidden' costs? Many users of GCs are convinced that they (GCs) are complex pieces of equipment and must be housed in environmentally controlled shelter. A GC can be intimidating. Why? These devices have an electronic section similar to that of a personal computer (CPU, communication interfaces and video displays); and they have an analytical oven that can consist of shut-off, vaporizing inject, column and back-flush valves, and, more important, such analytical units include multiple detector technologies such as thermal conductivity, flame ionization and flame photometric, and a variety of possible separation media, e.g., columns. Couple this mindset with the critical nature of the results being generated, and it is easy to understand why process GCs are often placed in shelters. Of course, some users have experienced performance issues with their GCs when atmospheric temperatures and/or pressures swing; they also contribute to the preference of placing a GC in a shelter.

What if the GC did not need to be placed in a shelter, or did not require the shelter to be temperature controlled? Yes, to properly analyze a sample stream, GCs require stable temperature, pressure and flowrate of the sample as it travels through the analytical oven. Variations in temperature can result in drifting baselines, peak shifts and even multi-phasing of the sample. Pressure and flowrate changes can also impact sample values if they are not controlled.

Minimizing analytical errors can be accomplished by using a properly designed sample handling system, appropriate transport tubing and an application-defined probe assembly. At no point in this extraction, transport or conditioning of the sample gas is a shelter required. The items listed here can be electrically or steam-heated and mounted outside in nearly any environment without compromising performance or safety. The costs associated with a shelter—including the shelter itself as well as the engineering and installation costs—have already been discussed. They are significant, but can they be removed or reduced?

Recently, field-mountable process GCs have been introduced to the industry and are gaining increasing acceptance. Field-mountable GCs are generally smaller and typically have more

FIG. 2 Field-mountable process GC.

limited application capability compared to traditional air-bath oven GCs. But the initial costs to house, install, operate and maintain these field-mountable process GCs are less than larger "conventional" GCs.

Issues of environmental impact, hazardous area classification, utility consumption, application capability, availability and maintainability are discussed and compared and costs assigned where possible. The total cost of installing, maintaining and operating process GCs will be examined over a hypothetical installation and 10-year period and compared to a traditional air-bath oven analyzer design and field-mountable transmitter designs.

Environmental. For a conventional GC, the instrument is designed for installation in an analyzer house. It is not recommended to be installed in the field without additional climate-control protection because of repeatability issues. It cannot withstand rain and is sensitive to high humidity. Normally, conventional GCs need some ambient temperature control to ensure oven temperature stability, particularly in low-temperature environments and those with widely varying temperature cycles.

For the new field-mounted GC, the instrument is designed to be installed directly in the field without any additional protection. Field-mountable GCs are designed to withstand rain, high humidity and a wide ambient temperature range—typically –20°C to 60°C (–4°F to 140°F)—without impact on their analytical performance. Housings are typically IP 56 or higher. A rain shield or three-sided rack can be included for those times when technicians must do maintenance on the equipment, but it is not required.

Hazardous area classification. For a conventional process GC, the area classification GC depends upon the manufacturer, but is normally Class 1 Division 2 Groups B, C and D, utilizing an appropriate purge mechanism. Some manufacturers offer Class 1 Division 1 Groups B, C and D. None of these instruments are explosion proof. Fig. 2 is a typical example of a conventional process GC.

The field-mountable GC derives its protection for flammable hazardous areas from its enclosure (Fig. 3). The instrument housing is explosion proof, and there is no need for an air purge to ensure rating. The typical area classification is Class 1, Zone 1, AEx d IIB+H_2, T4, Enclosure Type 4—various agency approvals, such as ATEX, CSA and IEC-Ex are often obtained.

Utilities. For the conventional GC, normal electrical requirements for the oven are from 1,140 W to 1,200 W during initial startup and 400 W to 500 W during normal service. Instrument air is required for cooling and purging of the electronics (Class 1 Division 1), as well as for the oven temperature air-bath heater. Some manufacturers also recommend purging electronic sections with "dry" instrument air to prevent the buildup of dust or moisture in them. Failure to do so can result in the premature failure of electronic board assemblies or components housed in this section of the process GC.

For field-mounted GCs, the instrument consumes less electrical power during initial startup and during normal use—often less than 150 W. The field-mountable GC does not require instrument air for any functions because of oven and housing design. Therefore, continuous heating of "plant air" is not required, reducing the power requirements. Pneumatic valves can be actuated safely by carrier gas. Electric sample shut-off valves, solenoids and sample stream switching valves can be utilized. Pneumatic sample valves and column valves are also utilized. Carrier gas follows a flow path from reference detector to oven columns/valves, and then to the measurement detector to minimize carrier gas consumption. The field-mountable GC provides significant utility cost savings over the useful life of the instrument.

Oven design capability. For a conventional GC, the oven heat is provided by a heating tube and heater coil. Because the oven space is large, air must circulate to ensure adequate temperature distribution and control. This arrangement is known as an air-bath oven. Almost all process GCs use air-bath ovens. Tight proportional, integral, derivative (PID) control of the oven temperature is normally used. (Some older process GCs have only proportional integral control.) This provides adequate temperature control; however, the large thermal mass of the oven makes it slow to heat up and cool down. Temperature stability upon initial power-up or after oven maintenance will take at least one hour to attain. Maximum oven temperatures vary depending upon the manufacturer. Typical upper limits are 180°C to 200°C. The larger internal space allows multiple detectors and valves to be housed. Sub-oven assemblies can also be installed, allowing for temperature programming that is required for applications like simulated distillation.

For the field-mounted GC, a central core is used for the oven. This is heated by block wrap-around heaters. The thermal mass of the oven assembly maintains temperature stability and transmits heat to the detectors mounted to the oven assembly. Tight PID control can be maintained because the oven's thermal response time is fast. The columns are near the detectors and heaters, allowing stable heating throughout the analysis. The entire oven

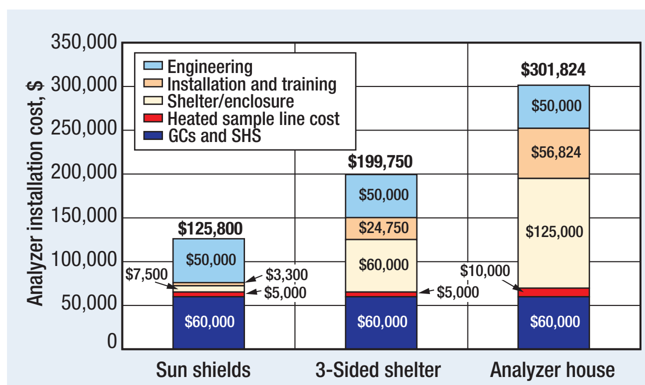

FIG. 3 Installation cost comparison of field-mountable and conventional process GC (1 GC).

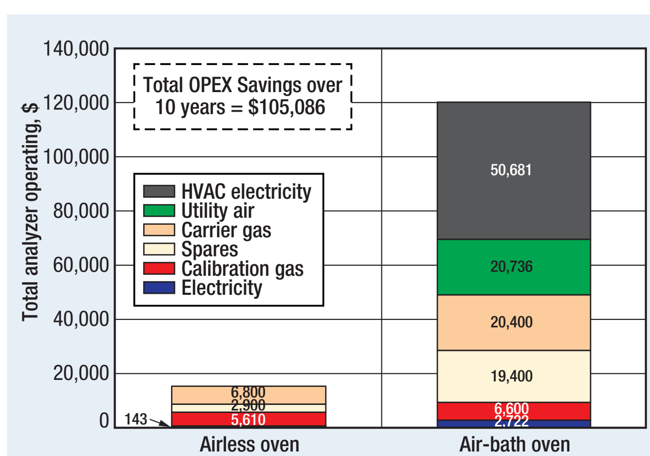

FIG. 4 Ten-year cost comparison of field-mountable and conventional process GC (1 GC).

assembly is enclosed in an insulation packing. This ensures the ambient temperature rating of the field-mountable GC—typically –20°C to 60°C (–4°F to 140°F).

A maximum of four sample/column switching valves (6-port or 10-port) can fit into the oven, based on the manufacturer. The oven can house up to two thermal conductivity detector (TCD) sets: TCD/TCD; or a flame ionization detector (FID) and TCD in a TCD/FID detector set. This is also dependent on the manufacturer.

TABLE 1. Basis for cost estimates

Utility and calibration costs		
Electricity cost	$0.05	$/kW-hr
Instrument air $ for 1000 scf	$0.80	$/1,000 SCF
Carrier gas cost	$170.00	$/cylinder
Calibration cost	$330.00	$/cylinder
GC data	**Air bath oven**	**Airless oven**
Utility air CFM	5	0
Electricity (W)	630	33
Calibration gas bottles/year	2	1.7
Carrier gas bottles/year	12	4
Annual spares and replacement parts	$1,940	$290
Shelter		
HVAC unit power	6.6	KW
HVAC description	CSA Certified Class I Div	
	2 Groups B, C & D,	
	includes freestanding 25 ft	
	fresh air stack, certified	
	to 130 mph wind	
Replacement A/C after 10 years	$21,620	

Given the compact design and the heating method of the analyzer, the maximum oven temperature is lower than that of a traditional GC, but can still be up to 150°C. The lower number of possible valves, reduced space for columns and lower temperature capabilities can all limit the number of applications capable by the field-mountable GC; in some instances, it can limit which high carbon number compounds can be analyzed. Programmed temperature type applications, such as simulated distillation, cannot be done.

Cycle times. Column configurations and oven temperatures for both the field-mountable GCs and conventional GCs do not differ significantly for most applications. Accordingly, the cycle times are relatively equivalent. A complete analysis of natural gas up to and including C_6+ hydrocarbon components, giving a measurement within 0.1 Btu in 1,000 Btus, for example, is accomplished in a field-mountable GC in four minutes.

Sample transport lag times. Conventional process GCs are usually installed in analyzer houses, which are often five times more expensive than the cost of a single GC. Therefore, an optimization of the analyzer house is done to place as many analyzers as possible into a single house. This rationalizes the cost of the house between various GCs. Location of the house is determined by plant geography (space available as opposed to the geographic distribution of the sample taps). This rarely allows for the optimizing transport lag. A conventional GC typically has longer lag times when compared to a field-mountable GC. A 200-foot ¼-in. sample line will introduce a two-minute transport lag into

TABLE 2. Installation cost comparison: Field-mountable GC vs. traditional GC

	1 Transmitter GC in sun shield	1 Transmitter GC in 3-sided shelter	1 Conventional GC in analyzer house
Number of GCs/enclosed house			1
Number of GCs/3-sided shelter		1	
Number of GCs/sun shield	1		
Number of 3-sided shelters		1	
Number of enclosed shelters			1
Gas chromatograph cost	$45,000	$45,000	$45,000
Sample system cost	$15,000	$15,000	$15,000
Sample line cost per ft-insulated Installed	$5,000	$5,000	$10,000
Engineering costs	$50,000	$50,000	$50,000
Enclosed house cost C1 D2 10 ft x 14 ft			$125,000
3-sided shelter cost C1 D2 6 ft x 6 ft		$60,000	
Sun shield for single GC cost	$7,500		
Enclosed shelter installation at site cost			$49,725
3-sided shelter installation at site cost		$20,800	
Sun shield installation at site cost	$650		
Analyzer installation cost	$650	$650	
Shelter startup and check-out cost		$1,300	$2,600
Training cost	$2,000	$2,000	$2,000
Instrument air piping (300 ft) cost			$2,499
			One-year cost estimate
Required capital	**$125,800**	**$199,750**	**$301,824**
Savings	**$176,024**	**$102,074**	

a control loop. The effect of this lag depends upon the control strategy, process dynamics and analysis cycle time. Additionally, compromises and costs in sample/speed loop disposal to a flare may have to be made to obtain fast sample transport times.

The field-mountable GC can be installed close to the sample tap to reduce the sample transport lag and to help optimize control response. A closely coupled field-mountable GC (30 ft to 40 ft) will typically have a 20-second sample lag time.

Installation considerations. For a conventional GC, typical extra expenses include engineering time and costs, additional labor associated with a shelter installation, safety systems for the enclosed space, pouring an installation pad and bringing plant instrument air to the conventional process GC. For a field-mounted GC, the design allows it to be mounted closer to the sample takeoff; so the sample line itself can be shorter. The installed cost is lower, and that can be significant when heat-traced sample lines are used. Fewer problems will be encountered obtaining a representative sample due to the sample characteristics changing during transport. Problems with clogging, two-phase flow and condensation are also reduced. The field-mountable GC can be freestanding, mounted to a pipe, or mounted in a simple three-sided shelter. The field-mountable GC will occupy less space in the plant than an analyzer house, and will simplify transportation of the analyzer to the final site.

Availability. Preventative maintenance needed by both the field-mountable GC and conventional GC is similar as is the time required to do this maintenance. Should oven substitutions be utilized, some field-mountable GC ovens can be completely replaced in approximately 20 minutes. Mean time to repair (MTTR) will depend upon the particular defect in question. Both the field-mountable GC and conventional process GC will require about 10 minutes of cool-down before components can be handled, plus the time to substitute any required components. It will take from 1 to 4 hours to re-establish temperature stability.

So how can you avoid or reduce the hidden costs?

When considering a new GC for your site, one should be able to determine whether a field-mountable process GC can be utilized for a specific plant need. If possible, using a field-mountable GC can significantly lower the costs associated with adding a process GC measurement. Tables 1–3 outline not only the upfront cost savings if a fully enclosed shelter can be eliminated, but also the expected cost savings over the life of the equipment. In this example, 10 years was selected. Tables 1–3 detail the differences between field-mountable and conventional process GC installations and life-cycle costs, and Figs. 4 and 5 add graphical representations of the comparative costs.

TABLE 3. Cost comparison field-mountable GC vs. traditional GC over 10 years

GC operation cost	Air bath oven	Airless oven	Savings
Electric cost	$2,722	$143	$2,579
Utility air cost	$20,736	$0	$20,736
Calibration gas	$6,600	$5,610	$990
Carrier gas	$20,400	$6,800	$13,600
Spares and replacement parts	$19,400	$2,900	$16,500
GC total operation costs	$69,858	$15,453	$54,405
		Total shelter and HVAC	**$50,681**
		Total OPEX savings	**$105,086**
		Total OPEX savings over 10 years	**$105,086**

A decision to add a process GC in a plant is often the result of extensive research and planning, and the benefits or required needs are well understood. However, many hidden costs are often not considered in the planning and budgeting phase(s). Selecting the appropriate GC and enclosure type can significantly reduce both capital and operational expenses. In appropriate applications, field-mountable GCs offer significant savings and greatly reduce total cost of ownership compared to conventional process GCs by reducing costs with climate controlled shelters, instrument air, electrical power, carrier gas consumption, installation costs, and also by reducing sample lag times. Typical installation cost savings, given the estimates and assumptions can be as much as $175,000, and the 10-year operational cost savings can be as much as $105,000. **HP**