

Manual of Petroleum Measurement Standards Chapter 22.6

Testing Protocol for Gas Chromatographs

FIRST EDITION, AUGUST 2015



AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Users of this Standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

Copyright © 2015 American Petroleum Institute

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the specification.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

	Page
1 Scope	1
2 Normative References	1
3 Terms, Definitions, Acronyms, Abbreviations, and Symbols	1
3.1 Terms and Definitions	1
3.2 Acronyms and Abbreviations	9
3.3 Symbols	9
4 Safety Considerations	10
5 Parameter Variations Affecting Device Performance	10
5.1 Selection of Relevant Test Parameters	10
5.2 Mandatory Baseline (Ideal Condition) Testing	10
5.3 Mandatory Non-Ideal Condition Testing	11
5.4 Non-Mandatory Special Testing	12
6 Performance Tests	13
6.1 Test Conditions	13
6.2 Test Installation	14
6.3 Test Results	18
6.4 Mandatory Baseline (Ideal Condition) Testing	19
6.5 Mandatory Non-Ideal Condition Testing	19
6.6 Non-Mandatory Special Testing	21
6.7 Testing Documentation	23
6.8 Testing Procedures	23
7 Test Facility Requirements	32
8 Uncertainty Analysis and Calculation	32
8.1 General	32
8.2 Types of Uncertainty Calculations	32
8.3 How to Calculate Uncertainty	35
8.4 Presentation of Uncertainty	43
9 Test Report	44
Bibliography	49

Figures

1 Parameter Variations and Information Produced by Mandatory Baseline Testing	11
2 Parameter Variations and Information Produced by Mandatory Non-Ideal Condition Testing	12
3 Parameter Variations and Information Produced by Non-Mandatory Special Testing	13
4 Example Installation for GC Testing	15
5 Example of Soak Periods and Transients in a Quantity of Interest for Tests of Transient Conditions ..	28

Tables

1 Applicability of Testing Procedures to Specific Tests	24
2 Example Test Gas Matrix	26
3 Example Repeatability Calculation	39
4 Example Calculation of Combined Uncertainties in GC Analysis	40
5 Example Calculation of Combined Uncertainties in Gas Properties	42

Introduction

Gas chromatographs (GCs) with improved design and performance claims are regularly introduced to the natural gas industry. Natural gas companies that purchase these GCs often have to debug these units, eliminate problems, and evaluate field performance characteristics and specifications of the units at their own expense. Often several companies form a consortium to conduct performance verification tests on such devices, while individual companies may also perform their own tests that unnecessarily duplicate effort.

The need for a standardized testing protocol to assess the performance of GC technology that will allow test results to be recognized by regulators and accepted by the user community is recognized by the natural gas industry. Test results published in a specified format and obtained by following an industry-accepted uniform testing protocol will benefit the natural gas industry and save the industry from duplication of effort. To meet this need, this general GC performance test protocol specifies the scope and reporting requirements of GC tests for repeatability, reproducibility, and response. This document specifies requirements for tests over a range of gas compositions, tests over a range of operating conditions, and tests with variations in other external parameters that may influence GC performance.

Many existing industry standards and accepted practices for the analysis of natural gas by gas chromatography were reviewed for the development of this protocol. Applicable standards at the time this document was written are listed in the Bibliography. It is not the intent of this protocol to replace these standards, but to allow those who perform the tests to incorporate these standards into the testing process where possible.

This protocol does not specify acceptance criteria for GCs undergoing tests, nor does it permit those who perform the tests to set acceptance criteria within the test procedures or judge the usefulness of a GC for a particular application. The end-users of test reports created using this protocol should choose acceptance criteria for GCs based on their individual applications and requirements.

Testing Protocol for Gas Chromatographs

1 Scope

This standard is a general gas chromatograph (GC) performance test protocol. It specifies the scope and reporting requirements of GC tests for repeatability, reproducibility, and response linearity. The protocol specifies requirements for tests over a range of gas compositions, tests over a range of environmental conditions, and long-term performance tests.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Manual of Petroleum Measurement Standards (MPMS), Chapter 14—Natural Gas Fluids Measurement, Part 1—Collecting and Handling of Natural Gas Samples for Custody Transfer, February 2006

GPA Standard 2198 ¹, *Selection, Preparation, Validation, Care and Storage of Natural Gas and Natural Gas Liquids Reference Standard Blends*

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1

acceptance criteria

Defined upper and lower limits for accepting the value of a process variable which is being monitored.

3.1.2

ambient conditions

The conditions (pressure, temperature, humidity, etc.) of the medium surrounding an object such as the case of a meter, instrument, transducer, etc.

3.1.3

atmospheric pressure

The pressure exerted by the weight of the atmosphere. At sea level, the pressure is approximately 14.7 pounds per square inch (101 kilopascals), often referred to as 1 atmosphere, atmospheric pressure, or pressure of one atmosphere.

3.1.4

barometric pressure

Ambient pressure in an absolute pressure scale monitored or displayed by a barometer.

3.1.5

bias

Any influence on a result that produces an incorrect approximation of the true value of the variable being measured. Bias is the result of a predictable systematic error.

¹ Gas Processors Association, 6526 E. 60th Street, Tulsa, Oklahoma 74145, www.gpaglobal.org.

3.1.6**calibration**

The process or procedure of adjusting an instrument, such as a meter, so that its indication or registration is in satisfactorily close agreement with a reference standard.

3.1.7**carrier gas**

A pure gas introduced so as to transport a sample through the separation unit of a gas chromatograph for analytical purposes.

NOTE Typical carrier gases are hydrogen, nitrogen, helium, and argon.

3.1.8**certificate**

A document issued by a nationally or internationally recognized facility or regulatory agency attesting to a specific property or performance.

3.1.9**certificate of analysis**

A document that indicates one or more properties of a material based on the test result of an analysis or the preparation of the material in accordance with a defined procedure.

NOTE 1 A certificate of analysis may be used to convey a laboratory test result, demonstrate conformance with a product specification, or provide information required for the certification of a reference material.

NOTE 2 Industry standards or regulation may dictate what additional information is to be contained in a certificate of analysis for it to be valid for its intended use.

3.1.10**certified composition**

A list of component concentrations in a gas blend that is verified and traceable to nationally recognized standards of weights and measures.

3.1.11**chromatogram**

A graph relating concentration (or mass per unit time) of solute leaving a chromatographic column, plotted against time, and taking the form of a series of peaks.

3.1.12**chromatographic method, gas**

A method of analysis by which the components of a gas blend are separated using gas chromatography.

3.1.13**component concentration**

The presence of a component in a mixture expressed in percentage or as a fraction of the total mixture.

3.1.14**composition**

Property of a gas blend given by the identity and the concentration of each component.

NOTE The term "content" is used as a generic term for the qualitative description of the composition of a gas blend without specifying any numerical values. In quantitative expressions of a gas blend composition, the selected quantity of composition, e.g. the mole fraction or the mass concentration, is used in conjunction with the name or the chemical formula of the component.

3.1.15**compressibility factor**

In reference to gases, a factor calculated by taking the ratio of the actual volume of a given mass of gas at a specified temperature and pressure to its volume calculated from the ideal gas law at the same conditions.

3.1.16**concentration**

A reference to any of a group of four quantities characterizing the composition of a mixture with respect to the volume of the mixture. The four quantities are mass concentration (mass per unit volume), amount concentration (moles per unit volume), volume concentration (volume per unit total volume), and number concentration (count per unit volume).

3.1.17**condensation**

The process by which a gas or vapor changes to its liquid phase.

3.1.18**confidence interval**

The range or interval within which the true value is expected to lie with a stated degree of confidence.

3.1.19**confidence level**

The probability that the true value will lie between the specified confidence limits, assuming negligible systematic error. This is generally expressed as a percentage, e.g. 95 %.

3.1.20**contaminant**

A substance that makes a gas blend or another substance impure or unclean through contact or mixing.

3.1.21**cylinder, gas**

A tank or pressure vessel used to store gases at pressures above atmospheric pressure.

3.1.22**dead band**

In reference to process instrumentation, the range through which an input signal may be varied, upon reversal of direction, without initiating an observable change in output signal.

3.1.23**dead volume**

The term 'dead-volume' refers to volumes within a chromatographic system which are not swept by the mobile phase that is flowing through most of the extra-column volumes.

3.1.24**density**

The density of a quantity of a homogeneous substance is the ratio of its mass to its volume. The density varies as the temperature changes and is therefore generally expressed as the mass per unit of volume at a specified temperature.

3.1.25**elution time**

The time after injection at which a component of an analyzed sample elutes from a chromatographic column and is sensed by the detector on a gas chromatograph.

3.1.26**environmental chamber**

An enclosure used to test the effects of specified environmental conditions on biological items, industrial products, materials, and electronic devices and components.

3.1.27**environmental conditions**

External conditions (such as shock, vibration, and temperature) to which a meter, transducer, instrument, etc., may be exposed during shipping, storage, handling, and operation.

3.1.28**error, measurement**

The discrepancy between the result of the measurement and the value of the quantity measured. The value of the quantity measured is a comparison value equal, according to the particular case, to the following: (a) the true value of the quantity, (b) the accepted true value, or (c) the arithmetic mean of the results of a series of measurements.

NOTE Definition (b) applies to the term as used in this document.

3.1.29**gas chromatograph**

An analytical instrument that separates mixtures of substances into identifiable components by means of chromatography. Separation is achieved by introducing a finite volume of a sample into a continuous inert gas flow (a carrier gas) that moves through one or more separation columns. The separation columns make use of differences in the adsorption behavior of the sample components onto a stationary phase, causing the components to move through each column at different rates. The components then leave the column at different times, and their amounts are measured individually by a detector.

3.1.30**heat trace**

A heating system consisting of a heating medium run in physical contact with process equipment or piping, externally applied and normally covered by insulation, that is used to maintain or raise the temperature of contents in piping, tanks, and associated equipment.

NOTE Typical heating media include steam tubing and electric trace heater cables, pads, or panels.

3.1.31**heating value, gross**

The quantity of heat released by the complete combustion of a material at constant pressure, the water vapor produced being condensed to liquid in equilibrium with its own vapor under the specified reference conditions, and the latent heat of condensation being included in the heat content. Also known as superior heating value.

NOTE 1 The term in current use is "heating value" or "specific energy." Historically obsolete synonyms are "heat of combustion" and "calorific value."

NOTE 2 Heating value may be expressed on a mass, molar, or volume basis.

3.1.32**heavy hydrocarbons**

Hydrocarbon components in a transmission-quality gas that tend to condense at operating pressures and temperatures. Typically, hexanes and heavier hydrocarbon gas components (C_{6+}) are considered to be heavy hydrocarbon gases.

3.1.33**hydrocarbon dew point**

A temperature at a given pressure at which hydrocarbon vapor condensation begins.

3.1.34**interlaboratory comparison**

Organization, performance and evaluation of measurements or tests on the same or similar items by two or more laboratories in accordance with predetermined conditions.

3.1.35**limit of detection**

The lowest analyte concentration to be reliably distinguished from the blank response or baseline response. It is the lowest concentration of a measurand reliably measured by an analytical procedure.

3.1.36**linearity**

The degree to which a response function describing the input-output relationship between an analyzed quantity and the signal produced by the analyzing device can be described by a straight line.

3.1.37**linear range**

Maximum and minimum limits of the output or error of a device within which the calibration curve fits over a stated monitoring range of the device.

3.1.38**manifold**

A pipe, tube, or chamber having multiple apertures for making connections.

3.1.39**measurand**

A physical quantity, property, or condition that has been or is to be measured.

3.1.40**nominal**

Describes a value assigned for the purpose of convenient designation; existing in name only.

3.1.41**normalize**

To adjust the representation of a quantity so that the representation lies within a prescribed range. Analyzed gas compositions are customarily normalized so that the total of all component concentrations equals 100 %.

3.1.42**operating conditions**

See environmental conditions.

3.1.43**outlier**

A result that differs considerably from the main body of results in a set.

3.1.44**parameters**

The values that characterize and summarize the essential features of measurements.

3.1.45**peak area**

The area enclosed between the peak and the baseline on a chromatogram.

3.1.46**peak integration method**

Method by which the area underneath each peak in a chromatogram is quantified, so as to identify component concentrations in the sample.

3.1.47**power supply**

A component of a system that provides a source of electrical energy at one or more voltages to other components of the system or to external devices associated with the system.

3.1.48**pressure regulator**

A valve that automatically limits the flow of a liquid or gas to a certain pressure.

3.1.49**purge**

To eliminate impure or undesirable substances.

3.1.50**purge loop**

A part of a sample collection system used to purge or flush unwanted samples from the system. Purge loops may be built to increase the flow rate of a sample stream through the system.

3.1.51**relative density**

Quotient of the gas density and the density of dry air of standard composition, specified at the same state conditions.

3.1.52**relative humidity**

A term used to describe the amount of water vapor in a mixture of air and water vapor.

3.1.53**repeatability**

Metering—The closeness of the agreement between the results of successive measurement of the same quantity carried out by the same method, by the same person, with the same measuring instrument at the same location, over a short period of time.

Laboratory test method—The difference between successive test results obtained by the same operator, with the same apparatus, under certain operating conditions, on identical test materials using the same test method.

NOTE The laboratory test method definition applies to the term as used in this document.

3.1.54**resistance temperature detector**

A temperature measuring device that operates on the principle of a change in electrical resistance in wire as a function of temperature.

3.1.55**resolution, measurement**

The smallest change in the quantity measured to which the instrument will react with an observable change in an analog or digital indication.

3.1.56**response factor**

The ratio between the quantity of an analyte and the peak area or peak height of a component peak in a chromatogram.

3.1.57**response function**

A function describing the relationship between the quantity of an analyte and the signal produced in a GC by the analyte. Response functions may be a constant ratio (a single response factor) or a non-linear relationship that produces different response factors for different analyte quantities.

3.1.58**sample**

A portion extracted from a total volume that may or may not contain the constituents in the same proportions that are present in that total volume.

3.1.59**sample line**

Tubing used to transport continuous or intermittent samples from its source to one or more analyzers.

3.1.60**sample probe**

A device extending through the meter tube or piping into the stream to be sampled.

3.1.61**sampling**

All the steps required to obtain a sample that is representative of the contents of any pipe, tank, or other vessel and to place that sample in a container from which a representative test specimen can be taken for analysis.

3.1.62**sampling system**

System capable of extracting a representative fluid sample and delivering it to an analytical device.

3.1.63**separation column**

A tube with material that isolates individual components, elements and/or compounds of a mixture having different physical or chemical properties. Separation columns in GCs serve to separate components in a sample stream so that they can be identified and quantified.

3.1.64**significant digits**

The number of meaningful digits that is displayed or recorded in a measurement. The last digit (and only the last digit) in a measurement is an estimate.

3.1.65**stability**

The ability of a measuring instrument to maintain its accuracy over a long period of time.

3.1.66**standard, API**

As per API Policy 104, a prescribed set of voluntary rules, conditions, or requirements concerned with the definition of terms; classification of components; delineation of procedures; specification of dimensions; construction criteria, materials, performance, design, or operations; measurement of quality and quantity in describing materials, products, systems, services, or practices; or descriptions of fit and measurement of size.

3.1.67**standard deviation, sample**

For a series of n measurements of the same measurand, the parameter characterizing the dispersion of the results and given by the formula:

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

where x_i is the result of the i -th measurement and $\bar{x}$ is the arithmetic mean of the n results considered.

NOTE The experimental standard deviation should not be confused with the population standard deviation of a population of size N and of mean m .

3.1.68**student's t distribution**

The distribution of the deviations of the mean values of the samples from the population mean, expressed as a proportion of the sample standard deviation (the samples being taken from normal distributions). It is used to set the confidence limits of the population mean, in particular in cases where the mean has been estimated from small samples.

3.1.69**test gas**

A gas blend of sufficient stability and homogeneity whose composition is properly established for use in the performance testing of a measurement system.

3.1.70**test GC**

The gas chromatograph which is to be tested to ascertain its performance characteristics.

3.1.71**thermal conductivity detector (TCD)**

A detector that measures the difference in thermal conductivity between two gas streams when a sample (gas blend) passes through the sample channel.

NOTE 1 The TCD is a dual channel detector, requiring a reference flow of pure carrier gas through the reference channel.

NOTE 2 The use of helium or hydrogen is recommended as carrier gas except when the sample contains either of these two substances to be measured.

NOTE 3 The detector consists of a bridge circuit; the change in resistance in the sample channel during the passage of the sample produces an out-of-balance signal that is the basis of the detection. The detector responds to all components except the carrier gas and is non-destructive.

3.1.72**thermocouple**

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference.

3.1.73**traceability**

The relation of a calibration, through a step-by-step process, to an instrument or group of instruments calibrated and certified by a national or international primary standard.

3.1.74**true value**

The theoretically correct amount. In practice, it is represented by the standard being used for comparison, such as a prover.

3.1.75**uncertainty**

A parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand, often expressed in terms of its variance or standard deviation.

3.1.76**unnormalized**

Not normalized; not adjusted to lie within a prescribed range. Raw gas compositions reported by GCs are typically unnormalized, such that the total of all component concentrations does not equal 100 %.

3.1.77**variable, measured**

The physical quantity, property, or condition that is to be measured. Common measured variables are temperature, pressure, rate of flow, thickness, velocity, etc.

3.1.78**verification GC**

A gas chromatograph that serves as the reference GC to evaluate performance characteristics of the test GC.

3.1.79**Warren reproducibility**

The comparison between the gravimetrically determined composition or calculated property of a calibration gas or test gas and the composition or property determined by GC analysis of the gas.

3.2 Acronyms and Abbreviations

ASTM	ASTM International (formerly American Society for Testing Materials)
GC	gas chromatograph
GPA	Gas Processors Association
ISO	International Organization for Standardization
NIST	National Institute of Standards and Technology
RTD	resistance temperature detector
TCD	thermal conductivity detector

3.3 Symbols

A_i	peak area of a chromatogram produced by component i
C_i	constant coefficient of a linear response function
$c_0, c_1, c_2 \dots$	coefficients of a nonlinear response function
H_v	gross heating value
r	repeatability

s	sample standard deviation
t	t -statistic computed from the Student's t distribution
u	standard uncertainty
U_{95}	95 % confidence interval
x_i	unnormalized mole percent or mole fraction of component i in a gas blend
y_i	normalized mole percent or mole fraction of component i in a gas blend
$\bar{z}$	average of multiple values of quantity z in a measurement sample
Z	compressibility factor
ρ	density

4 Safety Considerations

Facilities should follow all local, state, and federal laws regarding the use and handling of hazardous materials.

5 Parameter Variations Affecting Device Performance

5.1 Selection of Relevant Test Parameters

This section identifies the minimum set of test parameters required to permit the user to make an informed decision regarding GC performance. It is understood that the user or tester may add parameters for individual testing.

5.2 Mandatory Baseline (Ideal Condition) Testing

Baseline testing shall identify the influence of the following parameters on GC performance:

- test gas composition,
- calibration gas composition.

Baseline testing shall produce the following information, at a minimum, to characterize the GC's baseline performance:

- results of gross heating value and relative density calculations, if performed by the GC;
- repeatability of analyses;
- linear range of component response functions.

End-users of test reports created under this protocol should choose acceptance criteria for GC performance based on their individual applications and requirements. Industry standards containing acceptance criteria that may be of use are listed in the Bibliography. Tests for the limits of detection for gas components of interest are not included in this test protocol. Users are encouraged to consult with the GC manufacturer to determine the limits of detection for components of interest.

Figure 1 shows the relationship between parameter variations, test results, and performance data produced during baseline tests.

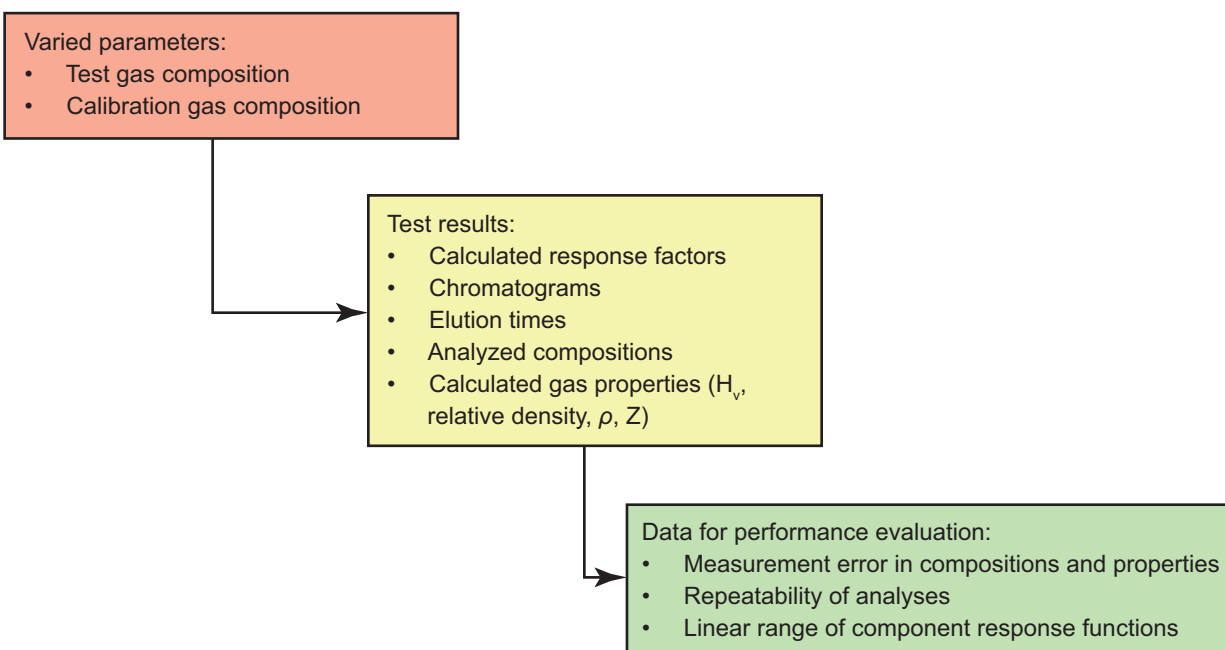


Figure 1—Parameter Variations and Information Produced by Mandatory Baseline Testing

5.3 Mandatory Non-Ideal Condition Testing

Mandatory non-ideal condition testing quantifies environmental effects on GC performance and the dynamic performance of the GC under changing conditions. The following test parameters are included in non-ideal condition tests:

- ambient temperature,
- barometric pressure,
- alternating test gas compositions representing varying sample streams,
- test gas temperature,
- test gas flow rate,
- carrier gas flow rate,
- carrier gas purity.

Non-ideal condition testing shall produce data quantifying the bias of GC analyses with respect to changes in these variables. For all variables except barometric pressure and carrier gas purity, non-ideal condition testing shall also produce data on the dynamic response of the GC to these changes. End-users should choose acceptance criteria for non-ideal condition testing based on their individual applications and requirements.

Figure 2 shows the relationship between parameter variations and performance data produced during non-ideal condition tests.

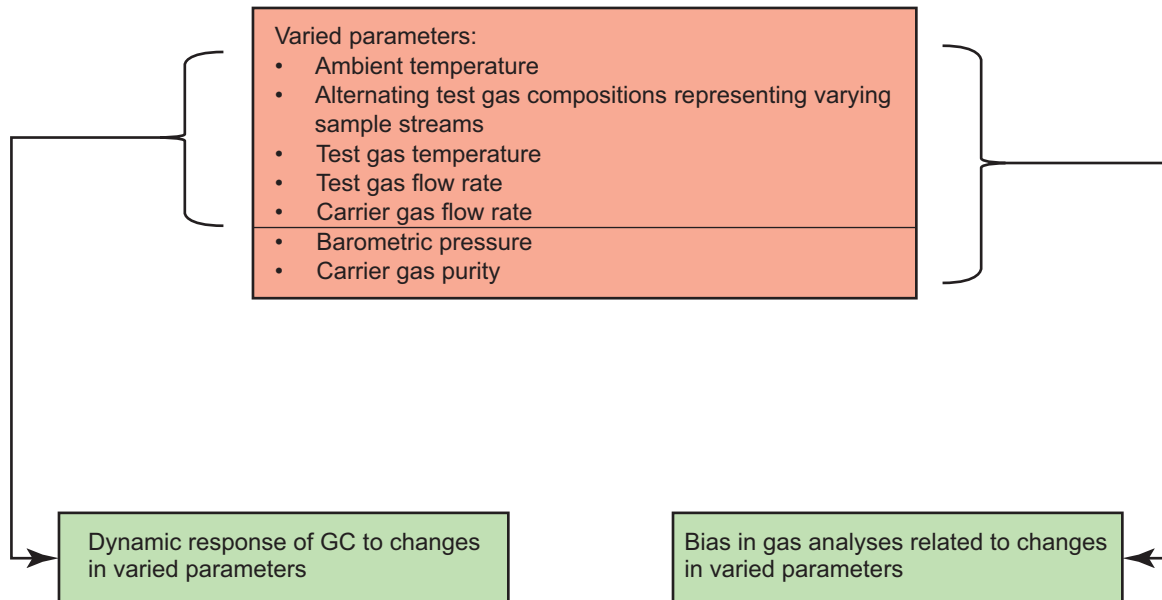


Figure 2—Parameter Variations and Information Produced by Mandatory Non-Ideal Condition Testing

5.4 Non-Mandatory Special Testing

Non-mandatory special testing quantifies the effects of external mechanical, electrical, and environmental conditions that may affect the performance of GCs. These conditions may include:

- mounting position (e.g. direct or remote mount to sample probe),
- relative humidity,
- mechanical vibration,
- “drop and topple” testing,
- power supply fluctuations,
- any other external parameter that may affect GC performance.

If performed, special testing shall produce data quantifying the bias of GC analyses with respect to changes in these conditions. For relative humidity and power supply fluctuations, special testing shall also produce data on the dynamic response of the GC to these changes.

Special testing may also include long-term stability tests. Such tests shall produce data quantifying changes in the repeatability and response linearity of the GC over long periods of time, and shall also produce data on any variables known through baseline tests and non-ideal condition tests to affect GC performance.

End-users should choose acceptance criteria for special testing based on their individual applications and requirements.

Figure 3 shows the relationship between parameter variations and performance data produced during special tests.