

CGA G-19—2017

**GUIDELINE FOR
NATURAL GAS SAFE HANDLING
AND OPERATIONS**

FIRST EDITION

PLEASE NOTE:

The information contained in this document was obtained from sources believed to be reliable and is based on technical information and experience currently available from members of the Compressed Gas Association, Inc. and others. However, the Association or its members, jointly or severally, make no guarantee of the results and assume no liability or responsibility in connection with the information or suggestions herein contained. Moreover, it should not be assumed that every acceptable commodity grade, test or safety procedure or method, precaution, equipment or device is contained within, or that abnormal or unusual circumstances may not warrant or suggest further requirements or additional procedure.

This document is subject to periodic review, and users are cautioned to obtain the latest edition. The Association invites comments and suggestions for consideration. In connection with such review, any such comments or suggestions will be fully reviewed by the Association after giving the party, upon request, a reasonable opportunity to be heard. Proposed changes may be submitted via the Internet at our web site, www.cganet.com.

This document should not be confused with federal, state, provincial, or municipal specifications or regulations; insurance requirements; or national safety codes. While the Association recommends reference to or use of this document by government agencies and others, this document is purely voluntary and not binding unless adopted by reference in regulations.

A listing of all publications, audiovisual programs, safety and technical bulletins, and safety posters is available via the Internet at our website at www.cganet.com. For more information contact CGA at Phone: 703-788-2700, ext. 799. E-mail: customerservice@cganet.com.

Work Item 13-109
Natural Gas Technology Committee

FIRST EDITION: 2017

© 2017 The Compressed Gas Association, Inc. All rights reserved.

All materials contained in this work are protected by United States and international copyright laws. No part of this work may be reproduced or transmitted in any form or by any means, electronic or mechanical including photocopying, recording, or any information storage and retrieval system without permission in writing from The Compressed Gas Association, Inc. All requests for permission to reproduce material from this work should be directed to The Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly VA 20151. You may not alter or remove any trademark, copyright or other notice from this work.

Contents	Page
1 Introduction.....	1
2 Scope	1
3 Definitions.....	1
4 Physical properties of natural gas	4
5 Overview of specific hazards for natural gas.....	5
5.1 Potential health hazards	5
5.2 Asphyxiation hazards	5
5.3 Cryogenic hazards for liquefied natural gas	6
5.4 Pressurized system hazards	7
5.5 Flammable gas hazards	7
5.6 Electrical hazards	8
5.7 Environmental hazards.....	8
6 Safe handling practices	9
6.1 Hazards and safety considerations	9
6.2 Personal protective equipment	9
6.3 Hazard mitigation in flammable atmospheres	10
7 Security considerations	10
7.1 Small volume facilities (less than 3500 lb).....	11
7.2 Medium volume facilities (between 3500 lb to 1 000 000 lb).....	11
7.3 Large volume facilities (more than 1 000 000 lb).....	12
7.4 Training.....	13
8 Process overview	13
8.1 Compressed natural gas	13
8.2 Liquefied natural gas	14
9 Vent systems.....	14
9.1 Visual inspection.....	14
9.2 Field repairs.....	15
10 Natural gas equipment and piping.....	15
10.1 Maintenance	15
10.2 Materials of construction.....	15
10.3 Piping systems and components.....	16
10.4 Pressure gauges	19
10.5 Strainers	19
10.6 Transfer components.....	19
10.7 Compressors	19
10.8 Pumps	19
10.9 Stationary containers.....	20
10.10 General pressure vessels.....	20
10.11 Heat exchangers	20
10.12 Portable containers.....	20
11 Emergency response	21
11.1 Site and hazard details	21
11.2 Personnel management	21
11.3 Notification, communications, reporting, and recording.....	22
11.4 On-site and off-site resources	22
11.5 Fighting natural gas fires	22
12 Risk assessment (HAZOP)	23

13	References	23
14	Additional references.....	25

Figures

Figure 1—Representative facility (gas supply system to a boiler)	11
Figure 2—Representative facility (LNG fueling station)	12
Figure 3—Representative facility (LNG bunkering).....	13

1 Introduction

This publication contains general information about the properties, transportation, storage, handling, and use of liquefied natural gas (LNG) and compressed natural gas (CNG). It is intended to provide guidance to anyone seeking more information regarding natural gas.

2 Scope

This publication is intended for natural gas users, shippers, carriers, distributors, equipment designers, safety administrators, and anyone seeking an introduction to natural gas. If more detailed or specialized information is required, consult your supplier. The information in this publication is intended to complement federal, state, provincial, territorial, local, and insurance company safety requirements.

This publication addresses the following:

- safe use and handling of products and systems that store, vaporize, transfer, and handle natural gas;
- hazards and safeguards associated with natural gas; and
- training of personnel involved with the handling of natural gas.

Natural gas is a combination of several different gases in differing concentrations. The guidelines contained in this publication assume that pipeline quality natural gas as defined in this publication is in use. See Table 1.

Many standards exist for the design, construction, installation, inspection, and examination of natural gas equipment and facilities. A complete description of the applicability of each standard is beyond the scope of this publication. See Section 14 for a list of additional references.

Where an applicable standard does exist, its rules shall be followed in conjunction with applicable local codes and regulations.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Asphyxiation

To become unconscious or die from the lack of oxygen.

3.2.2 Atmospheric pressure

Pressure exerted by the weight of the atmosphere at sea level. Equivalent to 14.696 psi or 101.325 kPa.^{1,2} The pressure exerted by a column of mercury (Hg) 760 mm high.

3.2.3 Compressed natural gas (CNG)

Natural gas that has been cleaned to meet a required quality standard, odorized, and compressed to a specific pressure into an appropriate container.

3.2.4 Confined space

Space not normally occupied by personnel that has limited or restricted openings for entry and exit, can lack adequate ventilation, and can contain or produce dangerous air contamination.

3.2.5 Container

Portable compressed gas cylinder or liquid container made in accordance with the U.S. Department of Transportation (DOT), Transport Canada (TC), or American Society of Mechanical Engineers (ASME) specifications.

3.2.6 Cryogenic

Temperatures below -130°F (-90°C).

3.2.7 Cryogenic burn

Damage caused to tissue when exposed to cryogenic temperatures.

3.2.8 Dampening device

Device installed at the inlet of a pressure gauge to remove pulsation from the gauge reading.

3.2.9 Design pressure

Most severe condition of coincident pressure and temperature expected in normal operation. This considers the maximum allowable working pressure (MAWP), static head of the product, and the vacuum if vacuum jacketed.

3.2.10 Emergency plan

Pre-established plan to be used as a guide in the event of an emergency.

3.2.11 Fatigue

Reduced strength in a material caused by cycling of pressure, temperature, or mechanical load.

3.2.12 Flammable

Degree to which a material is easily ignited in an oxidizing atmosphere.

3.2.13 Gas detector

Device designed to detect the presence of specific gases that could harm individuals if exposed to unacceptable concentrations.

3.2.14 Greenhouse effect

Process through which greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide, fluorinated gases) trap heat in the atmosphere.

3.2.15 Hazard and operability study (HAZOP)

Structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that can represent risks to personnel or equipment, or prevent efficient operation.

3.2.16 Liquefied natural gas (LNG)

Cryogenic natural gas in the liquid form.

¹ kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per [CGA P-11, Metric Practice Guide for the Compressed Gas Industry](#) [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2.17 Lockout/Tagout

Safety procedure used to ensure that sources of energy (e.g., electrical, chemical, pressure) are properly shut off, isolated, and labeled prior to the start of maintenance work. This condition is maintained during the work, and reversed when preparing for restart.

3.2.18 Low temperature embrittlement

Transition of materials to exhibit brittle properties when exposed to temperatures below the ductile range of the material.

3.2.19 Lower explosive limit (LEL)

Lower limit of flammability of a gas or vapor at ordinary ambient temperatures and pressures expressed in percent of the gas or vapor in air by volume. The LEL will vary with temperature and pressure.

NOTE—LEL is also referred to as lower flammability limit (LFL).

3.2.20 Maximum allowable working pressure (MAWP)

Maximum gauge pressure permissible at the top of a container in its operating position for a designated temperature.

3.2.21 Odorant

Substance added to a product to give it a particular scent or odor.

NOTE—Natural gas is typically odorized with an organic compound containing sulfur, resulting in a pungent smell to warn the public of a natural gas leak.

3.2.22 Overpressure

Pressure that exceeds the MAWP or design pressure of a system.

3.2.23 Oxygen deficiency

Atmosphere in which the concentration of oxygen is less than 19.5% by volume.

3.2.24 Personal protective equipment (PPE)

Equipment worn by personnel to decrease the risk of injury due to exposures to process hazards.

3.2.25 Pressure relief system

Safeguards installed to prevent overpressure of equipment.

3.2.26 Purge

Flow of air or an inert medium at a rate that will effectively remove any gaseous or suspended combustibles and replace them with the purging medium.

3.2.27 Risk assessment

Documented exercise to assess the risks of a specific operation to personnel and the environment. This process usually takes into account safety controls inherent in equipment, operating procedures, and personal protective equipment provided. Sometimes, it may be deemed appropriate to improve operational safety controls after undertaking a risk assessment.

3.2.28 Safeguards

Devices and procedures that mitigate risk.

3.2.29 Test pressure

Highest pressure difference the container wall withstands between the inside and outside during testing to meet the requirements of applicable regulations, codes, standards, or specifications.

3.2.30 Upper explosive limit (UEL)

Highest concentration of a flammable gas in an oxidant that will propagate when ignited.

NOTE—UEL is also referred to as upper flammability limit (UFL).

3.2.31 Wobbe Index

Indicator of the interchangeability of fuel gases such as natural gas, liquefied petroleum gas (LPG), and town gas and is frequently defined in the specifications of gas supply and transport utilities.

4 Physical properties of natural gas

Natural gas is a combustible, naturally occurring mixture of hydrocarbon gases composed primarily of methane. In its natural state, natural gas is odorless and colorless, making it hard to detect without specially designed equipment. Although natural gas can be stripped of its various hydrocarbon components to be used in a wide range of applications, it is primarily used as a fuel.

When working with or near natural gas, the following should be considered:

- it is a flammable, non-toxic gas that can cause asphyxiation in high concentrations;
- it is lighter than air, meaning that if it escapes, it will rise and dissipate unless confined such as in an unventilated roof;
- it has a lower explosive limit (LEL) ranging from 3.8% to 6.5%; and
- it has an upper explosive limit (UEL) ranging from 13% to 17%.

Depending on the chemical composition of the natural gas, the physical properties (i.e., density, heating value, combustion temperature, etc.) can vary. Chemical composition can also cause unwanted or unexpected chemical reactions (e.g., corrosion). To address potential hazards and prevent accidents, equipment designers and operators shall have a working knowledge and understanding of the chemical composition of the natural gas for the intended application. Equipment shall be operated within the composition limits for which it is designed.

A complete list of all potential hazards is beyond the scope of this publication. Some of the more common hazards are as follows:

- natural gas streams with a high content of sulfur and water are corrosive;
- natural gas streams that contain almost pure methane combusts at higher temperatures, potentially leading to early wear or melting of parts;
- LNG with a high percentage of ethane or other heavier hydrocarbon will weigh significantly more than natural gas that is mostly methane;
- combustion can occur if there is a release of natural gas (expected or unexpected) that is coupled with the right mixture of air and an ignition source; and
- natural gas streams containing mercury will corrode aluminum parts quickly.

Pipeline quality natural gas composition can vary significantly by region. Select constituents are listed in Table 1.

The physical properties of natural gas vary with composition. As shown in Table 1, the heating value of pipeline natural gas can vary by as much as 20% within the range of representative compositions. Other physical properties such as density, saturation temperature, etc. can vary just as widely. The designer and operator of the system should have an understanding of the physical properties for the composition used in their applications. A reputable source of the physical properties of compound mixtures is the National Institute of Standards and Technology (NIST) *Standard Reference Database 23* [2].

Table 1—Typical pipeline quality natural gas constituents

Constituent	Minimum	Maximum
Methane	75% mol	99% mol
Ethane	0% mol	10% mol
Propane	0% mol	5% mol
Butanes	0% mol	2% mol
Pentanes plus	0% mol	0.5% mol
Nitrogen, carbon dioxide, and other inerts	0% mol	4% mol
Carbon dioxide	0% mol	3% mol
Hydrogen sulfide	--	1.0 gr/100 scf
Mercaptan sulfur	--	1.0 gr/100 scf
Total sulfur	--	20 gr/100 scf
Water vapor	--	7.0 lb/mmmcf
Oxygen	0% mol	0.2% mol
Heating value	950 Btu/scf	1150 Btu/scf
Wobbe Index	1275 Btu/scf	1400 Btu/scf

5 Overview of specific hazards for natural gas

Natural gas systems and equipment are considered a process system with unit-specific hazards, as well as general industrial hazards such as dynamic (e.g., moving machines, vehicles), height or elevation, ergonomic, moving, and lifting hazards. Users should have an appropriate understanding of general industrial hazards as well as the unit-specific hazards discussed in this section before carrying out activities that can expose personnel to potential danger.

5.1 Potential health hazards

Natural gas in its gaseous state under normal conditions and at very low concentrations does not present an inhalation, ingestion, or skin hazard. At high concentrations, natural gas will reduce the available oxygen in the air resulting in symptoms of headache, nausea, dizziness, fatigue, and possibly coma and/or death. See Table 2 for a list of potential hazards.

5.2 Asphyxiation hazards

Asphyxiation is a condition in which an extreme decrease in the amount of oxygen in the body leads to loss of consciousness or death. It is arguably the greatest hazard in the gas industry because asphyxiating gases are invisible.

A decrease of oxygen content below 19.5% is considered hazardous. Oxygen deficiency can result from poor system design and layout or careless operational and maintenance practices. The risk of oxygen deficiency occurs most often from venting or disposal of nitrogen or natural gas. This risk increases significantly in confined spaces (e.g., buildings, poorly vented areas, pits) and in areas surrounding large gas release sources.

Attempting to breathe any atmosphere or process gas with little or reduced levels of oxygen can be fatal.

Safeguards and management systems should be in place to prevent asphyxiant gas exposure.

Table 2—Potential health hazards of natural gas

Exposure	Hazard
Eyes	Nonirritating. Under most circumstances, exposure to natural gas will not affect the eyes.
Skin	Nonirritating. Natural gas generates heat that can burn the skin. Under most other circumstances exposure to natural gas will not affect the skin.
Ingestion	Risk of ingestion is extremely unlikely.
Inhalation	Inhaled natural gas is considered to be non-toxic. The effects of inhalation of high concentrations of natural gas can cause the same effects as asphyxiation, including central nervous system depression (e.g., dizziness, drowsiness, headache, and similar narcotic symptoms), but no long-term effects if removed from the exposure area. Numbness, a chilly feeling, and vomiting have been reported from accidental exposures to high concentrations.
Chronic and carcinogenicity	Methane and ethane, the main components of natural gas, are considered practically inert in terms of physiological effects. At high concentrations, these materials act as simple asphyxiates and can cause death due to lack of oxygen.
Carcinogenicity	Occupational Health and Safety Administration (OSHA): No International Agency for Research on Cancer (IARC): No National Toxicology Program (NTP): No American Conference of Governmental Industrial Hygienists (ACGIH): No
Medical conditions aggravated by exposure	Individuals with pre-existing conditions of the heart, lungs, and blood can have increased susceptibility to symptoms of asphyxia.

Personnel shall be aware of the possibility of asphyxiation and frequently inform and remind others of this risk. Of particular concern are confined spaces, see Title 29 of the U.S. *Code of Federal Regulations* (21 CFR) Part 1910 for guidance on confined space entry, and CGA SB-2, *Oxygen-Deficient Atmospheres* [3, 4].

In areas where human occupancy may be necessary, adequate safeguards against oxygen deficiency shall be in place. A means for detecting the presence of natural gas in all areas where leaks, spills, or hazardous accumulations can occur shall be provided for example, odorant and gas detectors.

5.3 Cryogenic hazards for liquefied natural gas

A cryogenic leak can condense the moisture in the surrounding air. When cold boil-off gases condense the moisture in the surrounding air, it can create a visible fog. This fog can also be formed around cold equipment when no release of the cold liquid or vapor has occurred.

Fog clouds do not define the limits of a natural gas vapor cloud. Fog clouds define the area where the natural gas vapor is still cold enough to condense the moisture in the air. The natural gas vapor can extend well beyond the fog cloud depending on the product and atmospheric conditions. The dense fog clouds associated with the handling or transfer of cryogenic liquids can obstruct visibility and shall not be entered.

Care should be taken when handling cryogenic liquids to minimize fog so it does not create a visibility hazard or interfere with traffic or safety escape routes.

Natural gas vapor clouds pose many hazards including, but not limited to:

- asphyxiation;
- flash fire;
- cryogenic burns; and
- low temperature embrittlement of equipment.

A special hazard exists in a process system wherever LNG can be trapped between closed valves. As the liquid vaporizes through normal heat leak, the resulting pressure can cause the enclosed section of piping or equipment to fail. Thermal expansion valves shall be provided in accordance with 10.3.7.3.

5.4 Pressurized system hazards

Pressure energy becomes a hazard when it escapes or overcomes its containment, for example, vessel or transfer hose rupture. Pressure systems shall be restricted to their maximum allowable working pressure (MAWP) by control systems and relief devices. Proper maintenance procedures, including lockout/tagout as well as other management controls and systems, shall be in place to prevent exposure to high pressure hazards. Compliance with all such procedures and controls shall be mandatory.

Pressure systems shall be kept in good mechanical condition (i.e., limited corrosion, mechanical support) and protected from overpressure by pressure relief systems that are properly maintained. Maintenance procedures should identify minor deficiencies early to avoid catastrophic events, for example, fluid leakage before pressure system failure.

Pressure piping systems subjected to corrosion or fatigue shall be inspected at prescribed intervals as required by regulations or a risk assessment. Operational and maintenance procedures shall identify failures that could compromise the safe operation of the pressure piping systems (e.g., blocked or damaged relief systems, reduced material strength due to internal or external corrosion).

Pressure retaining components shall be properly isolated and depressurized prior to being removed for service.

5.5 Flammable gas hazards

This section describes the potential for incidents associated with operating and maintaining flammable gas systems, highlights specific hazards involving natural gas, and explains safeguards and precautions that shall be in place.

5.5.1 Presence of flammable gas

The vapor mixture of a flammable gas in air will ignite with the presence of an ignition source and burn within a well-specified range of concentrations. The mixture will not burn when the concentration is below the LEL or above the UEL.

Before conducting any work that can cause ignition, the operator shall ensure the area is free of flammable gases to prevent any possible fire or explosion.

When conducting hot work, refer to NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work* for additional information [5].

5.5.2 Natural gas storage and containment

Natural gas shall be suitably stored and contained to prevent flammable or explosive events. Natural gas has its own requirements to ensure safety, including NFPA 70, *National Electric Code*® electrical zone classifications for ignition sources and intrinsically safe equipment and segregation from other process equipment, occupied buildings, confined spaces, etc. [6].

For large scale storage (more than 100 000 gal of LNG), the analysis of gas dispersion and potential heat radiation should be considered. For such analysis, refer to NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)* [7].

As natural gas discharges can ignite, they shall not be allowed to accumulate. Natural gas discharges shall be dispersed in a safe manner, typically via a vent or flare stack.