

This document licensed for the sole use of the purchaser. It may not be shared with any other person or used after the expiration date without the express written permission of the CGA. Any unauthorized use, reproduction, distribution, or modification of this printed page will result in a \$5,000 liquidated damages fee plus loss of access to CGA publications for one year for your company.

CGA G-4.15—2019

**VACUUM-JACKETED PIPING IN
LIQUID OXYGEN SERVICE**

FIRST EDITION



PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has published [CGA G-4.15, *Vacuum-Jacketed Piping in Liquid Oxygen Service*](#), jointly produced by members of the International Harmonization Council.

This publication is intended as an international harmonized standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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 website, 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 15-111
Atmospheric Gases and Equipment Committee

NOTE—Appendix A (Informative) is for information only.

FIRST EDITION: 2019

© 2019 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.

This document licensed for the sole use of the purchaser. It may not be shared with any other person or used after the expiration date without the express written permission of the CGA. Any unauthorized use, reproduction, distribution, or modification of this printed page will result in a \$5,000 liquidated damages fee plus loss of access to CGA publications for one year for your company.

Contents	Page
1 Introduction.....	1
2 Scope and purpose	1
3 Definitions.....	1
4 General hazards and requirements.....	2
4.1 Oxygen hazards	2
4.2 Hazards and requirements for vacuum-jacketed piping systems in liquid oxygen service.....	2
5 Design	3
5.1 General vacuum-jacketed piping description.....	3
5.2 Vacuum-jacketed piping design considerations	5
6 Oxygen compatibility	14
6.1 Selection of materials	14
6.2 Cleaning	14
7 Fabrication, testing, quality assurance/quality control, and shipping	14
7.1 Fabrication, testing, and quality assurance/quality control requirements.....	15
7.2 Shipping requirements.....	15
7.3 Site installation	16
8 Operations and maintenance	16
8.1 General considerations.....	16
8.2 Inspection	17
8.3 Vacuum reading	18
8.4 Maintenance	18
8.5 Equipment isolation	18
8.6 Management of change.....	18
8.7 Protecting open systems when piping or piping components have been removed.....	19
8.8 System blowout after major maintenance	19
8.9 Change of service	19
9 References	19
10 Additional references.....	20
Figures	
Figure 1a—Example of vacuum-jacketed piping—Cutaway view.....	4
Figure 1b—Example of vacuum-jacketed piping—Cutaway view.....	4
Figure 2—Example of a vacuum-jacketed piping run in service	5
Figure 3—Internal and external bellows.....	7
Figure 4a—Cutaway of a typical bayonet design.....	9
Figure 4b—Cutaway of a typical flange bayonet design	9
Figure 5—Example of a V-band clamp design.....	10
Figure 6—Example of a flanged connection	10
Figure 7—Typical vacuum field closure cutaway view	11
Figure 8—Example of a vacuum-jacketed riser	12
Figure 9—Examples of well supported bayonet connections	13
Figure 10—Examples of hangar and roller supports.....	14
Figure 11—Example of an iced bayonet connection.....	17
Table	
Table 1—Examples of vacuum-jacketed pipe weight per length	13
Appendix	
Appendix A—List of typical suitable materials (Informative)	21

1 Introduction

In recent years, the increase in the size and production capacity of air separation plants has led to a corresponding increase in the capacity of liquid oxygen storage and transfer installations at production sites.

Multiple violent ruptures of vacuum-jacketed piping systems used in liquid oxygen service have been experienced in the industrial gas industry. These incidents have occurred due to a variety of causes including:

- Liquid oxygen leak into the annular space followed by reaction with incompatible material(s), for example, contaminants, palladium oxide getter, activated charcoal;
- Liquid oxygen leak into the annular space followed by contact with materials that have not been properly cleaned for oxygen service; and
- Liquid oxygen leak into the annular space followed by rapid overpressurization of the annular space.

The intent of this publication is to ensure that a minimum, uniform level of safety is provided throughout the industrial gas industry for the protection of the public and industry employees.

2 Scope and purpose

This publication addresses vacuum-jacketed piping used in any stationary industrial gases applications including air separation plants, other industrial gases facilities, and customer installations in liquid oxygen service. This publication provides guidance to those persons directly associated with the design, installation, operation, and maintenance of vacuum-jacketed piping systems used to transfer liquid oxygen. The user is cautioned that this publication is not a complete design handbook and does not do away with the need for competent engineering judgment and interpretation. It is suggested that the user review any special problems or concerns with the liquid oxygen supplier and/or vacuum-jacketed piping manufacturer who can provide guidance. This publication does not supplant, but is intended to complement, national and local regulations and codes of practice.

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 Nonmetallic material

Any material, other than metal, or any composite material in which the metal constituent is not the most easily ignited component and for which the individual constituent cannot be evaluated independently (see [ASTM G63, Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service \[1\]](#)).¹

3.2.2 Vacuum-jacketed piping specifier

Individual or organization that has responsibility for defining technical and/or procurement requirements for vacuum-jacketed piping systems.

3.2.3 Getter

Reactive material that removes trace contaminants from a gas.

3.2.4 Annular space

Volumetric space between the inner pipe and outer jacket that contains insulation materials and is evacuated to lessen heat flux.

4 General hazards and requirements

4.1 Oxygen hazards

Oxygen is not flammable but supports and accelerates combustion. Oxygen concentrations greater than 23.5% create fire hazards but not asphyxiation hazards. Flammable materials, including some materials that are normally relatively nonflammable in air, burn very rapidly in high oxygen concentrations. As concentrations increase greater than 23.5% oxygen, ease of ignition of clothing increases dramatically. Once ignited by even a relatively weak ignition source such as a spark or cigarette, clothing can burst into flames and burn rapidly. Greater than 40% oxygen, the fibers on clothing and body hair and oil are subject to flash fire when ignited, which spreads rapidly over the entire exposed surface. For additional information on oxygen hazards, see [CGA P-45, Fire Hazards of Oxygen and Oxygen-Enriched Atmospheres \[2\]](#).

An oxygen hazard analysis is a method used to evaluate risk of fire in an oxygen system. It assesses the probability of ignition or consequence of ignition (ignition versus sustained burning based on operating conditions). It can be used to select materials for new designs or to evaluate the compatibility of materials. In general, acceptance criteria for materials in a given application depend on two key factors, ignitability and flammability. For more information on oxygen hazard analysis and risk assessment, see [CGA G-4.14, Design, Manufacture, Installation, Operation, and Maintenance of Valves Used in Liquid Oxygen and Cold Gaseous Oxygen Systems \[3\]](#).

4.2 Hazards and requirements for vacuum-jacketed piping systems in liquid oxygen service

Hazards that relate to the use of vacuum-jacketed piping systems in liquid oxygen service include:

- Noncompatible adsorbent—Nonoxygen compatible adsorbent shall not be used in the annular space due to potential high reactivity with any oxygen that leaks into the annular space;
- Oxygen leaking into the annular vacuum space can react with any nonmetallic components within the annular space including internal supports. Liquid oxygen can also rapidly vaporize and lead to an overpressurization of the vacuum jacket;
- Noncompatible annular insulation materials—These materials can react with oxygen that leaks into the annular space. Annular insulation materials shall be hydrocarbon-free and compatible with oxygen;
- Piping and component contamination—All piping and components, including the annular space, that can come into contact with oxygen (for example, in the event of an inner pipe leak) shall be cleaned to meet oxygen cleanliness requirements (see [CGA G-4.1, Cleaning of Equipment for Oxygen Service \[4\]](#));

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

- Oxygen leaking from the inner pipe into the annular space can react with getter material (for example, palladium oxide). Additionally, if the getter material leaks from its container and comes into contact with aluminum, subsequent oxygen exposure can lead to ignition of the aluminum wrapping material; and
- Liquid oxygen leaking into the annular space or the gap between the male/female parts of the bayonet and being totally evaporated can, in the long term, enrich hydrocarbons on the metal surface until an ignition occurs. In addition, an uncontrolled pressure release can occur due to liquid evaporation.

5 Design

5.1 General vacuum-jacketed piping description

Piping systems that store and convey cryogenic fluids present unique considerations. From a safety standpoint, the extremely low temperature of cryogenic fluids exposes the user to potential serious irreversible injury. From an operational standpoint, excessive heat in-leak and pressure loss, both which effect fluid phase quality, can prevent efficient operation. Poorly insulated lines are not cost effective and ice or frost that develops can cause water damage to the surrounding area and falling ice can damage equipment. Vacuum-jacketed piping with radiation shielding safely addresses these concerns. The outer jacket remains at near ambient temperature while providing the most efficient and stable thermal insulating effect available.

Because the majority of these piping systems are installed in the common workplace, safety regulations and general liabilities shall be considered. Piping shall be designed and manufactured in accordance with American Society of Mechanical Engineers (ASME) [B31.3, Process Piping](#) or an equivalent piping code that takes into account temperature, pressure, fluid, and service conditions to which the piping will be operated thereby providing the common safety guide for engineering design, fabrication, and testing [5].

To produce this class of specialty piping, a well-regulated production facility with qualified personnel is essential to perform fabrication, leak checking, examination, and other quality control functions. When field assembly or modification is required, care is needed to maintain the vacuum, or to re-establish a quality vacuum in the field, use only qualified personnel.

Figure 1a and 1b show two examples of a section of vacuum-jacketed piping. Figure 2 shows an example of vacuum-jacketed piping in service.

5.1.1 Vacuum superinsulation

System of thermal insulation that includes:

- Double shell insulation space (annular space) where static vacuum is limiting heat transfer by conduction and convection;
- Blanket of alternate layers of highly reflecting shields and insulating spacers to prevent heat transfer by radiation as well as conduction between shields; and
- Adsorbent placed in the vacuum space in order to achieve an adequate level of vacuum at low temperature by adsorption of residual gases and moisture.

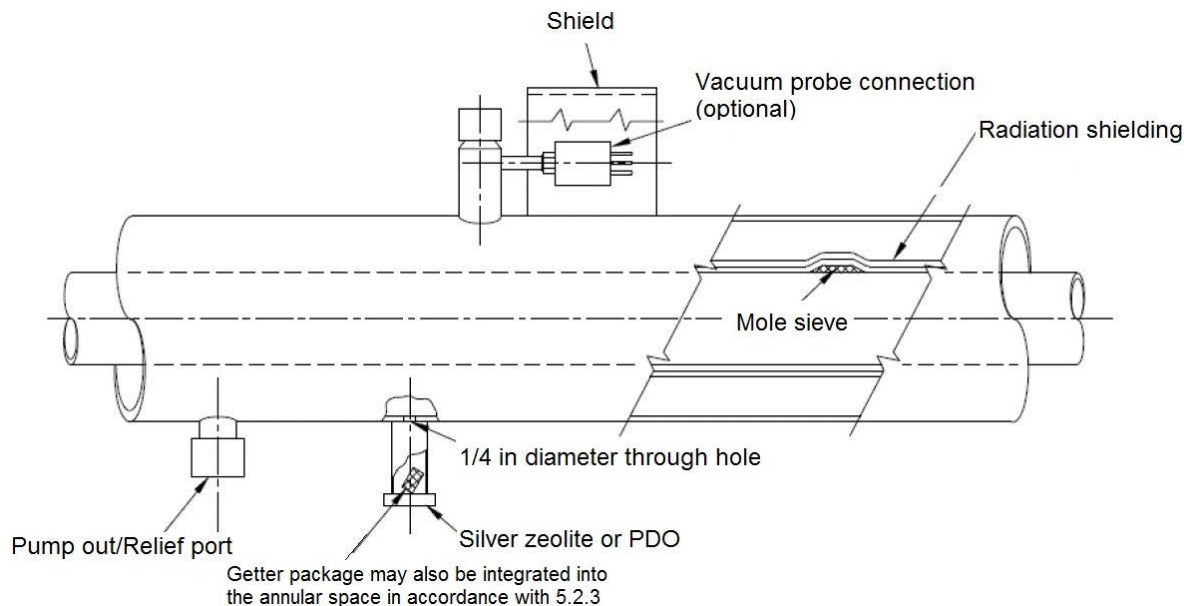
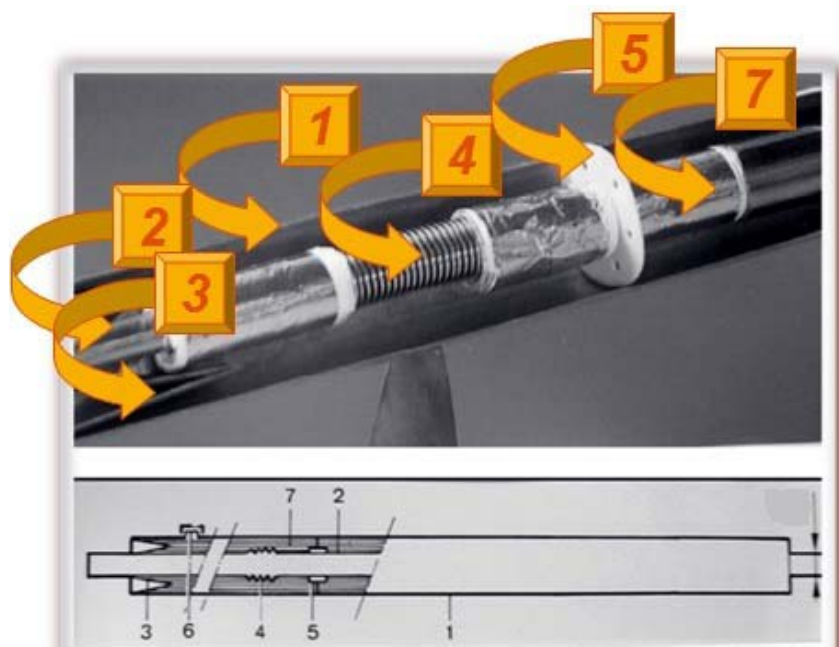


Figure 1a—Example of vacuum-jacketed piping—Cutaway view



1	Outer jacket
2	Inner pipe
3	Thermal barrier
4	Expansion bellow
5	Spacer
6	Vacuum port/relief port (not shown in photo)
7	Radiation shielding
NOTE—The getter and molecular sieve are not shown in this figure.	

Figure 1b—Example of vacuum-jacketed piping—Cutaway view



Figure 2—Example of a vacuum-jacketed piping run in service

5.2 Vacuum-jacketed piping design considerations

Vacuum-jacketed piping shall be configured with the following design considerations.

5.2.1 Inner pipe

- The design and manufacturing of the vacuum-jacketed piping shall be in accordance with [ASME B31.3](#) (or equivalent piping code) to meet the maximum allowable working pressure (MAWP) and fluid requirements [5];
- Inner pipe material and fittings, including flanges, forged fittings, elbows, tees and reducers, and compensation devices such as bellows or flexible hoses shall be of suitable material and thickness for the cryogenic temperatures, MAWP, and fluids to which it will be exposed. Fittings shall comply with ASTM A403, *Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings* and ASTM B16.9, *Factory Made Wrought Buttwelding Fittings* or equivalent code [6, 7]. See Appendix A for a list of typical materials; and
- A flexibility analysis shall be performed to consider the thermal compensation of the inner pipe due to thermal contraction of the inner pipe (selection of bellows, identification of the fixed-point supports, and sliding supports). The expansion joints (bellows) shall be installed according to *Standards of the Expansion Joint Manufacturers Association, Inc.* [8]. See 5.2.4. The flexible hoses shall be designed and manufactured according to [ASME B31.3](#) or an equivalent code [5]. See 5.2.6. The bellows should be dimensioned for a minimum of 1000 cycle loads. The designed expansion length of the bellows should only reach up to 80% of its maximum allowable expansion.

The available bending length of the process tubes shall be sufficient so that the bending forces are within material specification. This bending length depends on the stiffness of the tube. To reduce the forces, prestressing of the tube lengths equal to half the contraction may be introduced during assembly.

The inner pipe shall be supported within the vacuum outer jacket by a support system designed to:

- absorb thermal loads on the inner pipe when partially or completely filled with product;
- be compatible for liquid oxygen application;
- minimize heat losses;