



CGA P-34—2022

SAFE HANDLING OF OZONE-CONTAINING MIXTURES INCLUDING THE INSTALLATION AND OPERATION OF OZONE-GENERATING EQUIPMENT

THIRD EDITION

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.

Full document details: CGA P-34-2022

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.

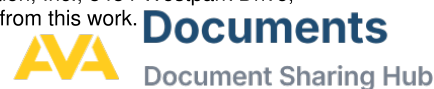
Work Item 18-051
Atmospheric Gases and Equipment Committee

NOTE—Technical changes from the previous edition are underlined.

THIRD EDITION: 2022
SECOND EDITION: 2014
REAFFIRMED 2007
FIRST EDITION: 2001

© 2022 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., 8484 Westpark Drive, Suite 220, McLean, VA 22102. You may not alter or remove any trademark, copyright or other notice from this work.



Contents	Page
1 Introduction.....	1
2 Scope	1
3 What is ozone?.....	1
4 Ozone safety information	3
5 Ozone generator operation	6
6 Storage and transportation of ozone	11
7 Emergencies	11
8 References	11
9 Additional reference	12

Tables

Table 1—Physical properties of ozone	2
Table 2—Personal exposure effects and regulatory limits	4

1 Introduction

This publication was developed to satisfy the demand for information concerning the safe generation and handling of ozone-containing gas mixtures. Assistance was provided by the International Ozone Association in preparation of this document.

2 Scope

This publication presents general information regarding the characteristics of ozone, the means by which it can be handled safely, and the safe installation and operation of ozone-generating equipment. Requests for specialized, technical information regarding specific types of ozone-generating equipment should be directed to the manufacturers of equipment used to produce ozone gas.

This publication is intended primarily for users of ozone and manufacturers of equipment used to produce ozone. It is limited to dry (less than 100 ppm moisture) oxygen-ozone, air-ozone mixtures at pressures up to 2 atm (gauge), and up to 16 weight percent ozone.

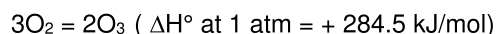
This publication does not address ozone generator power supply units (PSUs). Recommendations regarding operations, maintenance, and safeguards for PSUs can be obtained from the ozone generator manufacturer.

This publication also does not address specific operating and maintenance specifications for ozone generators, including the variety of coolants used, freeze protection, corrosion aspects, etc. This information is critical to the safe operation of ozone generators and shall be obtained from the ozone generator manufacturer due to the varying requirements for different systems.

3 What is ozone?

3.1 Physical and chemical properties

Ozone is an unstable molecule produced from elemental oxygen, often called an allotropic (the existence, especially in the solid state, of two or more crystalline or molecular structural forms of an element) form of oxygen. The overall reaction for ozone formation is described by an endothermic reaction:



Since ozone is unstable, it must be generated at the point of application. The ozone molecule having a molecular weight of 48 is made of 3 oxygen atoms bound by equal oxygen-oxygen bonds at an obtuse angle of 116 degrees 49 minutes. This structure is inherently unstable and is the reason for ozone's powerful oxidizing ability.

Some physical properties of ozone are listed in Table 1. The toxicity of ozone gas and its exposure limits are provided in Section 4.

As a gas, ozone is 1.7 times heavier than air. At ordinary temperatures and at high concentrations, ozone is a bluish gas, but at concentrations at which it is generated for normal use, this color is not noticeable.

At -169°F (-112°C), ozone condenses into a dark blue liquid that explodes easily. Concentrated oxygen/ozone mixtures (above approximately 20% ozone) can easily explode, either in the liquid or vapor state. Such explosions can be initiated by small amounts of catalysts, organic matter, shocks, or sudden changes in temperature or pressure.

Under the conditions where ozone is generated commercially, concentrations of ozone in oxygen above 20 weight percent do not occur. Manufacturers of ozone-generating equipment are not aware of any incidents involving explosive decomposition of ozone-oxygen or air-ozone mixtures in well-designed and properly maintained generators. If any incidents in equipment downstream from ozone generators have occurred, the

Compressed Gas Association (CGA) does not have sufficient information to ascertain the nature of these incidents or their causes [1].¹

Ozone is about 13 times more soluble than oxygen in water at standard temperature and pressure. It readily decomposes to oxygen from which it is formed. This decomposition is very rapid in water containing impurities that can react with the dissolved ozone, slower in high purity water, and slower still in gas mixtures. Gas phase ozone transport is, therefore, the best means of conveying ozone from the generator to the reactor or point of use to ensure the greatest amount of ozone is available.

Table 1—Physical properties of ozone

	U.S. Units	SI Units
International symbol ¹⁾	O ₃	O ₃
Molecular weight ¹⁾	47.998	47.998
Density of gas at 70 °F (21.1 °C) and 1 atm ¹⁾	0.1204 lb/ft ³	1.929 kg/m ³
Specific gravity of the gas at 70 °F (21.1 °C) and 1 atm (air = 1) ¹⁾	1.612	1.612
Specific volume of the gas at 70 °F (21.1 °C) and 1 atm ¹⁾	8.31 ft ³ /lb	0.5185 m ³ /kg
Specific gravity at boiling point	1.574	1.574
Boiling point at 1 atm ¹⁾	−168.3 °F	−111.3 °C
Melting point at 1 atm ¹⁾	−314.5 °F	−192.5 °C
Critical temperature ¹⁾	10.13 °F	−12.15 °C
Critical pressure ¹⁾	802.4 psia	5533 kPa, abs
Critical density ²⁾	33.7 lb/ft ³	540 kg/m ³
Latent heat of vaporization at boiling point and 1 atm ¹⁾	136.1 Btu/lb	316.46 kJ/kg °C
Specific heat of gas, C _p at 77 °F (25 °C) and 1 atm ¹⁾	0.196 Btu/lb °F	0.820 kJ/kg °C
Solubility in water, vol/vol at 32 °F (0 °C) ³⁾	0.64	0.64
Weight of liquid at boiling point ^{2) 3)}	84.4 lb/ft ³	1352 kg/m ³
¹⁾ CGA <i>Handbook of Compressed Gases</i> , 4 th ed [2]. ²⁾ Nebel, "Ozone" in <i>Encyclopedia of Chemical Technology</i> , Vol. 14, Second Ed. (New York, NY: John Wiley & Sons, Inc. 1967) pp. 410-432 [3]. ³⁾ von Mailfert, <i>Compt. Rend.</i> 119:951(1894) [4].		

3.2 Manufacture

The conversion of oxygen into ozone requires the rupture of the very stable bond of the oxygen molecule and the combination of the subsequently formed "singlet" oxygen atom with another oxygen molecule. This is accomplished commercially by passing a clean, dry, oxygen-containing gas through an electrical discharge. In this method, high voltage is applied across a discharge gap and collisions occur between electrons and oxygen molecules. A fraction of these electrons have sufficient kinetic energy (approximately 6 or 7 eV) to dissociate the oxygen molecule to form ozone, while the remaining electrons release their energy as heat.

A typical ozone generator uses a corona discharge, where lined glass or ceramic dielectric tubes are fitted inside water-cooled stainless steel tubes with an annular gap (discharge gap) between the two surfaces. Oxygen-containing gas is passed through the annulus (discharge gap) and the high voltage applied across the gap results in ozone generation.

Total hydrocarbons (THC) in the oxygen-containing gas, expressed as methane equivalent, should be less than 40 ppm by volume or the maximum recommended by the generator manufacturer. For more information, see

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